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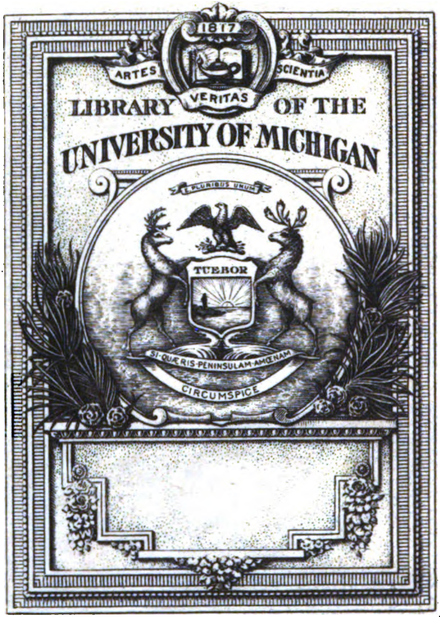

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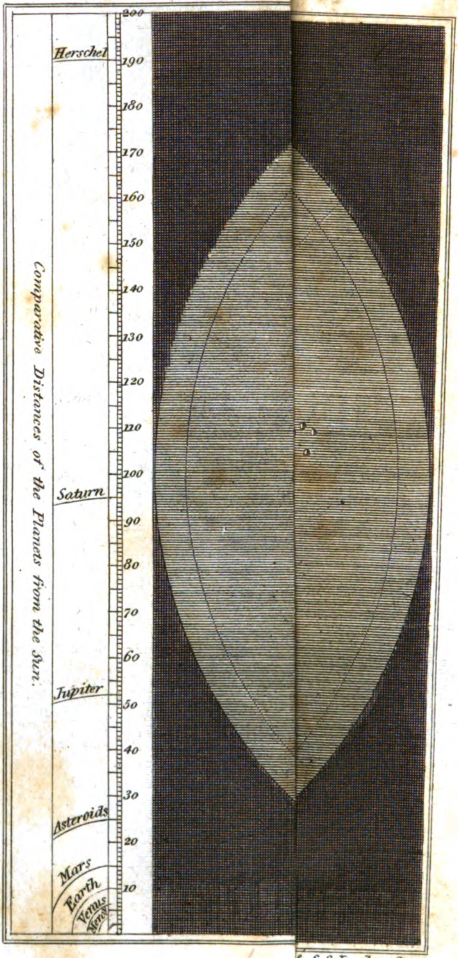

Comparative Distances of the Planets from the Sun.

& S. S. Jocelyn Sc.

UNIV OF

ELEMENTS

OF

ASTRONOMY,

DESCRIPTIVE AND PHYSICAL;

IN WHICH

THE GENERAL PHENOMENA OF THE HEAVENLY BODIES AND THE THEORY OF THE TIDES ARE FAMILIARLY EXPLAINED, AND ILLUSTRATED BY NUMEROUS DIAGRAMS FROM ENGRAVINGS ON COPPER PLATES.

THE WORK IS DESIGNED TO FACILITATE THE STUDY OF A SCIENCE PECULIARLY USEFUL, INTERESTING, AND SUBLIME; AND IS INTENDED FOR SCHOOLS, ACADEMIES, SEMINARIES FOR YOUNG LADIES, LYCEUMS, AND FOR PRIVATE READING.

BY HERVEY WILBUR, A. M.

——Heaven
Is as the Book of God before us set,
Wherein to read His wondrous Works.
Milton.

FOURTH EDITION.

WORCESTER:
PUBLISHED BY DORR, HOWLAND, & CO.
1834.

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TO THE FIRST EDITION.

WHILE engaged in the delivery of Astronomical Lectures, auxiliary to other important measures for the intellectual and moral improvement of the young, the inquiry has often been made, "What small Manual on Astronomy would you recommend to our perusal while attending your Course?" I knew of none, which exactly pleased me. I determined to take bones and sinews for a new body, from some recent English materials in my hands, and attempt to give them form, complexion and motion myself. How far this treatise will meet the necessities, or receive the approbation of the Public, the Author must leave for others to decide.

In this SECOND EDITION, grateful acknowledgements are tendered to the Public for the rapid sale of the First Edition; a sale unprecedented in the introduction of a *new* school book. Some improvements and additions are now introduced.

It is believed, that the present Appendix will supersede the necessity of using in schools any other work for solving problems on the globes.

Gift
Professor L. Karpinski
4-13-1934

DEDICATION.

While this Manual is commended to the lenity and patronage of those conducting the Literary Institutions and Lyceums of our land; and while the other numerous circles of Ladies and Gentlemen in our principal cities who have generously patronized his Lectures are not forgotten; to the Officers and Members of the New-York Mercantile Library Association this small volume is affectionately inscribed.

Should it contribute in any degree, profitably to employ a leisure hour in their counting rooms, in contemplating topics to which, with an enthusiastic interest highly creditable to themselves, they have listened in the lecture room, it would give new pleasure to one, who considers those hours among the most privileged hours of his life, when permitted week after week to address more than eight hundred Gentlemen, destined in Providence to exert the highest measures of commercial influence.

With ardent desires, that they may each shine in a brighter firmament when every star of evening is blotted out,

I remain, their obliged and humble servant,
H. WILBUR.

New-Haven, Aug. 18, 1829.

TESTIMONIALS,

Which Instructers and City Papers of the first respectability have given.

From Rev. T. H. Gallaudet, Principal of the Connecticut Asylum for the deaf and dumb.

The course of Lectures on Astronomy, by the Rev. Hervey Wilbur, which I have attended in this city, (one of which by the aid of very beautiful and striking illuminated diagrams, was made both instructive and highly interesting to the Deaf and Dumb pupils in the Asylum,) is in my opinion deserving the attention and patronage of all who wish to promote in a popular and perspicuous form a diffusion of knowledge in a department of Natural Science, tending in an eminent degree to improve the intellectual and moral character of man.

Hartford, *Dec.* 28, 1828.

From the Principal of a Select High School of rare excellence at Utica.

Mr. Wilbur.—Dear Sir, I cannot refrain from expressing my entire satisfaction with your course of Lectures. Their moral and intellectual effect, will no doubt be salutary in the highest degree. Many of your infant auditors, as well as grayheaded, have, while listening to your truly interesting lectures, and viewing your splendid diagrams, imbibed sublimer ideas of the Creator's power and wisdom, as exhibited in the material universe, than they would have had, had they not heard you, till, loosened from this clay tenement, they shall view the Creator's works in the light of eternity.

The moral reflections which you so appropriately and eloquently introduced, I trust will be the means of bringing some at least within the attraction of the Sun of righteousness, whose light unclouded they shall enjoy when the material universe shall be no more.

I hope, Sir, you will traverse the United States, and lecture not only in our cities and large towns, but in all our small villages, that all may enjoy the intellectual and moral light which illumines your path.

Your obedient Ser't,
C. BARTLETT.

From a well conducted Seminary by Friends at Leicester, Mass.

The teachers of Mulberry Grove Boarding School present to Hervey Wilbur their thanks for the instruction received by them and their pupils, in the course of Astronomical Lectures which he has recently given them. While the profound attention of the pupils evinced their interest in the lectures, their advances in the science attest to the qualifications of the Lecturer, and the utility of his manner of impressing the memory. They desire to be included in this expression of unqualified and unsolicited approbation.

SARAH EARL AND SISTERS.

From Miss C. Beecher's celebrated School.

Miss Beecher is happy to avail herself of the opportunity to acknowledge the great pleasure and benefit which has been received by such of the teachers and pupils of the Hartford Female Seminary as have attended Mr. Wilbur's Astronomical Lectures.

She considers the apparatus used by Mr. W., in connexion with his lectures, as being much superior to any thing of the kind she has ever known, and as eminently adapted for communicating a clear and general knowledge of the subject of Astronomy. She believes that all who attend these lectures will feel that no money could be more profitably spent in procuring either pleasure or benefit.

Hartford Female Seminary.

I attended, with my pupils, less than half Mr. Wilbur's Course of Lectures in the winter of 1829. I was much pleased, and favourably impressed of the advantage that might have been derived from attention to the whole course.

E. SMITH.

New-York, *January*, 1830.

Several of the principal Schools and Seminaries in Boston, Hartford, New-Haven, New-York, Philadelphia, and Baltimore, have attended these Lectures with similar feelings to those already expressed.

"*Astronomical Lectures.*—We had the pleasure last evening of attending Mr. Wilbur's introductory lecture on Astronomy. Mr. Wilbur is master of his subject, and the comparisons and illustrations by which he possesses the hearer's mind of his own clear, just conceptions, are eminently ingenious and happy. His apparatus is admirable for his purpose. We are much pleased with his whole plan and manner, and for the pleasure and advantage of our fellow-citizens, hope he may have crowded audiences."—*N. Y. Journ. Com.*

Other papers in New-York, and the principal papers in Boston, Philadelphia, Baltimore, and some other cities, have spoken in terms of warm commendation, both of the Lecturer and his apparatus

PREFACE.

The impression has been too common, that the physical sciences must not be studied till the education was nearly completed. This error needs to be corrected. With books and instructers, adapted to the capacity of the learner, no matter how early the mind is occupied with the properties, the combinations and motions of material bodies. And we do not hesitate to say, that no study can be made more interesting to mere childhood than Astronomy. It is conversant about the earliest, the greatest, and the brightest objects of their attention. If sufficient simplicity of language were used, the mind in childhood might be scientifically turned to "the Sun shining in his strength; to the Moon walking in brightness; and to the stars, differing one from another in their glories." Children in common schools might have a new impulse given them, if this science were familiarly explained there. And the time cannot be distant, when Astronomy will be taught *nearly* as early and as generally as Geography. Then the leaves of a volume, ever open, will be found having legible inscriptions for the husbandman as well as the scholar; and the shepherd-boy will again know and sing, "The heavens declare the glory of God."

To facilitate this object was the design of this treatise. Its style will be found intelligible to every attentive reader. Its illustrations, it is believed, have more simplicity, on some of the more difficult topics of this science, than any other astronomical work. And while it carries forward the pupil through all that is important in descriptive and physical astronomy, (much farther than other treatises for schools have done,) it is afforded at about one half or two thirds of their prices.

The use of this work is not intended as a substitute for attendance on Lectures where practicable. For it is believed that no method of teaching and learning Astronomy, is so interesting and useful as in the form of Lectures, accompanied with instruments and diagrams. The expression of the Lecturer's countenance, the intonations of his voice, and appropriate gestures, will rivet attention more than mere paper and ink can do: the more fixed our attention, the more deep and abiding the impressions made on our minds.

APPARATUS will enable us to acquire ideas clearly, and almost instantly, on some topics, where it would be difficult otherwise to obtain them. For instance, the influence of gravitation among the planets, in accelerating or retarding their motions, is better understood in five minutes examination of an Orrery in motion, than in hours or weeks, or perhaps months of mere reading. The use of DIAGRAMS is often indispensable to the acquisition of correct ideas in some of the sciences. The most able lecturers in our colleges, have in Natural Philosophy, and particularly in that branch of it called Astronomy, always used diagrams. But ILLUMINATED DIAGRAMS are of recent invention; and though considerable expense attends their use, they are incomparably superior to others. Nothing will so irresistibly attract and rivet our attention as these *illuminated diagrams*. Indelible images of them will be transferred through the eye to the memory, and borne with us to our firesides, and to our pillows. These images will powerfully aid us in recollecting the facts and illustrations given in the lecture room. And habits of rivetted attention may thus be formed or invigorated, that will be of great utility to us in every other path of science or pursuit of life.

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INTRODUCTION.

As introductory remarks, it may not be uninteresting or unprofitable, to present some of the claims of Astronomy, and glance at its history.

The fears which superstition has originated, and by which it has agitated our race, are greatly diminished by recent advances in this science. Either luminary may have its light obscured by Eclipses; the Comet's luminous train may stretch itself one fourth across the horizon; the Aurora Borealis may crimson the sky or span the heavens with an arch, and no terrors be felt, where this science is understood.

The husbandman is benefitted, both in seed-time and in harvest, by the light this science has thrown around him. The mariner, by its moonlight, to discern his longitude, traverses fearlessly the bosoms of oceans, five thousand miles from those shores, of which he dared not before to lose the sight. The merchant now commits to winds and waves his treasures, and expects them safely returned with large increase.

Geography has received a new continent from the confidence of Columbus, that the earth was spherical. History and chronology have had their facts confirmed, or their errors corrected, by astronomical calculations carried backward. It may be safely said, that all the arts and sciences, all the business and employments of man, have been highly benefitted by the advances made in this science.

But its intellectual and moral influence, renders it of inestimable value. With a field of immeasurable extent to be explored, with magnitudes, distances, and motions, vast and astonishing; the intellect becomes expanded, and the imagination enriched by every acquisition here made. And the moral sensibility which can discern, and appreciate infinity of excellence, will find all its energies elevated and inflamed, by the ennobling and sublime discoveries it every where makes of the Creator's perfections.

HISTORY.

Within a few centuries subsequent to the Deluge, Astronomical observations were made in China, in Hindostan, at Nineveh, at Babylon, and in Egypt. But the Greeks first gave method, and body, and form to this science. It is even believed, that Pythagoras five hundred years before the Christian era, discovered and taught the outlines of the true theory of the solar system. If so, 2000 years rolled away before it was again revived.

About 130 years after the birth of Christ, Ptolemy, an Egyptian Astronomer, published and defended the theory, which bears the name of Ptolemaic, but which was a mere accommodation of the science to the popular prejudices of the illiterate multitude. It supposed the Earth at rest in the centre of the Universe, with all the other material worlds revolving around it from east to west in 24 hours, while the Moon, the planets, and the Sun had other motions of less regularity, but all acknowledging Earth as their centre.

Other Egyptian Astronomers soon discovered, that the motions of Mercury and Venus, could not be reconciled with the Ptolemaic theory. They therefore concluded these two planets revolved around the Sun, as their centre. This theory is denominated the Egyptian.

About the commencement of the 16th century, Copernicus taught that the Sun is the centre of all the planetary motions. Galileo, Kepler, Newton, and La Place, by their inventions and discoveries, have since established this theory on an immoveable basis. The ephemeral hypothesis of Tycho Brahe, appears to have been invented more to allay the fears of superstition, than to subserve the interests of science.

ELEMENTS OF ASTRONOMY.

CHAPTER I.

GENERAL VIEW.—THE SUN.

ASTRONOMY is that sublime and useful SCIENCE, which treats of material worlds, and is divided into *Descriptive, Physical,* and *Practical, Astronomy.*

Descriptive Astronomy teaches the magnitudes, densities, distances, and diversified motions of the SUN, the PLANETS, COMETS, and FIXED STARS, with their interesting vicissitudes of day and night, summer and winter; and other sublime PHENOMENA in their circumstances.

Physical Astronomy developes the laws of motion, or the uniformity, in which the irresistible energies of their Author govern the mighty movements of material worlds.

Practical Astronomy relates to Astronomical Instruments and Observations, and will be omitted in this elementary treatise.

Among the celestial bodies, the Sun and Moon are termed *luminaries;* the others are called *stars.* Stars are also distinguished into *planets* and *fixed stars.*

The PLANETS, though they appear like the fixed stars, are all opaque, or dark bodies, moving in a regular order round the Sun, from west to east, receiving light from that luminary, and shinin only by reflected light.

What is ASTRONOMY? How may it be divided? What is *descriptive astronomy?* What is *physical astronomy?* What is *practical astronomy?* What are called *luminaries?* Are all *apparent* stars, *fixed stars?* What are *planets?*

Some of the planets have satellites or moons. There is also another order, called *comets*, with long luminous trains, which pursue very eccentric courses.

The names of the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, and Herschel; with four small ones, called Asteroids, named Ceres, Pallas, Juno, and Vesta.

These are called *primaries*, and there are also eighteen satellites or moons, called *secondaries*.

The Earth has one; Jupiter, four; Saturn, seven; and Herschel, six.

THE SUN.

The Sun is the source of light and heat, and the centre of our Solar or Planetary System. Its form is nearly that of a sphere or globe. Its diameter is about 886 thousand miles, and its circumference about 2 million 700 thousand miles.

Some authorities make the Sun's diameter more, others less.

Its distance from the Earth is 95 millions of miles. Its magnitude is more than a million of times larger than our own planet. The Sun has generally been thought a globe of real fire, but some suppose it to be an opaque body, surrounded by a luminous atmosphere.

A number of dark spots may be seen, by means of a telescope, on different parts of the Sun's surface. These consist of a *nucleus*, which is much

---

What are satellites? What are *comets*? What are the names of the planets and the asteroids? How are planets and satellites distinguished? How many *secondaries* are there? and how are they distributed?

What is the *centre* of our system? What are its dimensions? What its distance from the Earth? What its proportionate magnitude? What were the opinions of the ancients respecting it? What are those of some modern philosophers? What is usually seen on it through a telescope?

darker than the rest, surrounded by a mist or smoke; and they are so changeable as frequently to vary during the time of observation. Some of the largest of them exceed in square miles the surface of the whole Earth, and are often seen for months together. Very rarely, no spots are visible.

Dr. Herschel supposed that the Sun is surrounded by an atmosphere of a phosphoric nature, composed of various, transparent and elastic fluids, by the decomposition of which, light is produced, and lucid appearances formed, of different degrees of intensity. Openings in these fluids are the *spots.*

The density of the Sun being less than one fourth that of the Earth, it will be obvious, that with one million 400 thousand times the bulk of this planet, it has about 330 thousand times as much matter, and its attraction at its surface is 27 times as powerful, as the attraction of the Earth. For light, color, and heat, we are indebted to the Sun's influence.

The Sun has THREE motions. One motion is round the common centre of gravity of all the bodies, belonging to our system. Another motion is its rotation on its axis. And a sublimer motion still, is that towards the constellation Hercules.

We infer, that it has the first motion from the known laws of gravitation. That it has the second motion, in a period of 25¼ days, we infer from an observation of its spots, passing across its disc. That it moves towards the constellation Hercules, is inferred from the divergency of stars in that direction, and the convergency of stars in the opposite direction.

What description can be given of these spots?

What is Herschel's opinion of the Sun?

What is the density of the Sun? How much more matter than the Earth? What is its comparative attraction? For what are we indebted to the Sun's influence? How many motions has it?

What evidence that it has the first? What the second? What the third?

The apparent mean diameter of the Sun, as seen from the Earth, is 32 minutes and 1 second; as seen from a planet revolving round a fixed star, it would have no perceptible disc.

CHAPTER II.

MERCURY.

THE nearest planet to the Sun, is called Mercury. Its diameter is 3200 miles; its density 9 times the density of water, and the amount of light enjoyed, 7 times as great as at the Earth. Its mean distance from the Sun, is 37 millions of miles. It turns on its axis in 24 hours, and revolves round the Sun in 88 days; at the rate of more than 100 thousand miles the hour, or 30 miles the second.

Though small, this planet has a very bright appearance, slightly tinged with blue; but as it never appears 30 degrees distant from the Sun, it is rarely seen.

Both Mercury and Venus have varying phases, like the Moon, proving them to be opaque bodies, shining with light borrowed from the Sun; and also demonstrating, that they revolve in orbits of inferior magnitude to the orbit of the Earth. Hence they are called *inferior* planets.

What is the *apparent* mean diameter of the Sun? If distant as a fixed star how would it appear?

What planet is nearest to the Sun? What are its dimensions? What its density? What its amount of light? What is its distance from the Sun? What is the period of its *rotation?* What of its revolution round the Sun, and at what rate?

What is its appearance?

What proves that Mercury and Venus are opaque bodies and nearer to the Sun than the Earth? What are they called?

If the orbit of Mercury exactly coincided with the orbit of the Earth, and that planet was always moving in the plane of the Ecliptic, it would several times each year, appear crossing the disc of the Sun. These would be transits. But as the orbit of Mercury inclines 7 degrees to the plane of the Ecliptic, transits can occur only at the nodes; making from 12 to 14 such transits in each century. The last occurred in November, 1822. Others may be predicted for May, 1832, and November, 1835. Mercury's disc appears 10 seconds broad. Wallot supposes it has an atmosphere, and Schroeter calls its mountains ten miles high.

VENUS.

VENUS is the second planet in distance from the Sun; and much exceeds all the others in splendor. Its diameter, according to Herschel, is more than 8000 miles; its density is six times that of water; and its distance from the Sun, 68 millions of miles. The time of its rotation on its axis is 23½ hours; of its revolution round the Sun, 224 days, at the rate of about 84 thousand miles the hour. The inclination of its orbit to the Ecliptic 3°, and of its axis to the plane of its orbit, is supposed to be 75°, making its torrid zone extend within 15°, of either pole. The light of the Sun is twice as great as at the Earth, and falls on a similar atmosphere to our own, and on mountains, by some astronomers, considered four times as high, as the highest on our globe.

What is a transit? About how many transits of Mercury occur in a century? When was the last? When will there be others? What is the apparent diameter of this planet? In what respects is it supposed to resemble the Earth?

What planet is the *second* from the Sun? What is its magnitude? What its density? What is its distance from the Sun? What is the period of its rotation? What of its revolution? At what rate the hour? What inclination has its orbit to the Ecliptic? What its comparative light? What are the supposed elevations of its mountains?

Venus is morning star when westward of the Sun, and evening star when eastward; and will continue morning or evening star, a considerable time more than half the revolution of the planet, because the Earth is moving in nearly a parallel line. Its least apparent diameter is 17 seconds, and its greatest diameter 57 seconds: proving its range of distance from the Earth, to vary from 27 to 163 millions of miles. About 35 days before or after its inferior conjunction, its light is such as to cast a shadow by night, and to be visible at noonday.

Two transits of Venus like those of Mercury, occur at the nodes, once in 120 years. The two last were in 1761, and 1769, and were of great utility in determining, with accuracy, the distance of the planets from the Sun. The next transits will be in 1874 and 1882.

This subject will be resumed in another chapter.

The causes why the inferior planets sometimes appear stationary, and sometimes direct or retrograde in their motions, will be easily understood by an attentive examination of Plate ii. Figure 1.

CHAPTER III.

THE EARTH.

The Earth is next to Venus, as we recede from the Sun. It is 7912 miles in its polar, and 7938 in its equatorial diameter. Its density is 5 times the density of water; its mean distance from the Sun,

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When is Venus morning star? When evening star? Why each, more than half its orbit? What variations in its apparent diameter? What in its distance? When does it give most light?

How often are there transits of Venus? When were the last? When will there be others?

How will you account for the retrograde and stationary appearance of the planets?

What are the dimensions of the Earth? What is its density?

95 millions of miles; the time of its rotation, almost 24 hours; and of its revolution round the Sun 365¼ days, moving at the rate of 68 thousand miles the hour. The inclination of the Earth's axis to its orbit is such, that the Sun appears directly over head at noon, to the extent of 23 degrees and 28 minutes on either side of the Equator. This occasions the variations in the length of days, and of the seasons; topics which will be resumed in a subsequent chapter.

That the Earth is a globe, is conclusively proved from each one of the following facts. A person at the Equator, would see the north polar star barely above the horizon, but as he travelled north, it would become more elevated till his arrival at the pole, when it would be immediately over his head. A traveller, journeying due east under the Equator, would have the Sun arrive at the meridian, one hour earlier for every 1040 miles over which he travelled. The earth has been frequently circumnavigated. A ship going out to sea, has its hull, or lowest part, disappear first, demonstrating that the ocean is convex, as seen at the bottom of Plate vii. The shadow of the Earth in eclipses of the moon, is always circular on every side. The other planets are known to be spherical. Matter, in the rain drop and in the world, tends to this form.

The connection between the rotation of the Earth on its axis, and its spheroidal form, or greater equatorial, than polar diameter, will be discussed in Physical Astronomy.

THE MOON.

The Earth has one satellite, the Moon. Its diameter is about 2180 miles, its density, like its primary; its mean apparent diameter 31½ minutes;

—its distance from the Sun?—the time of its rotation?—of its revolution?—and its hourly rate? What distance from the Equator is the Sun ever vertical? For what will this account?

By what 7 arguments can it be demonstrated, that the Earth is a globe? What is the 1st?—the 2d?—the 3d?—the 4th? the 5th?—the 6th?—the 7th?

What is the magnitude of the moon? What is its density?

and its mean distance from the Earth about 240 thousand miles.

It turns once on its axis in 27⅓ days; the period in which it revolves once round the Earth, in a direction from west to east, and once a year it accompanies its primary round the Sun. The Moon is a dark body, shining only by reflection. This is proved, from its varying phases, and its eclipses; topics to be resumed in a future chapter.

Light is unequally reflected from different parts of the moon's disc, as viewed by the unaided eye. When examined by a telescope of high magnifying powers, the cause of this inequality becomes obvious. The surface of the moon is highly diversified by mountains, precipices and plains. The location of hundreds of these, has been ascertained, and names assigned to them. As the moon always presents nearly the same side to the Earth, and has an atmosphere only 1½ miles high, the mountains and cavities can be measured. See a beautiful and accurate telescopic map, Plate i. Figure 5.

Schroeter, makes the highest mountain more than five miles high; and the deepest cavity more than 3½ miles deep, and 40 miles in diameter. Herschel makes them less. The more even parts, or plains, are the darkest. Though some of them have the names of seas given to them, it is doubtful whether seas, or even large lakes, exist there. Water may exist in small quantities. Some of these plains have conical hills rising in them, with circular cavities near the summits. Many of the highest mountains appear to have been volcanoes, and a few are considered such at present. Dr. Herschel saw three which

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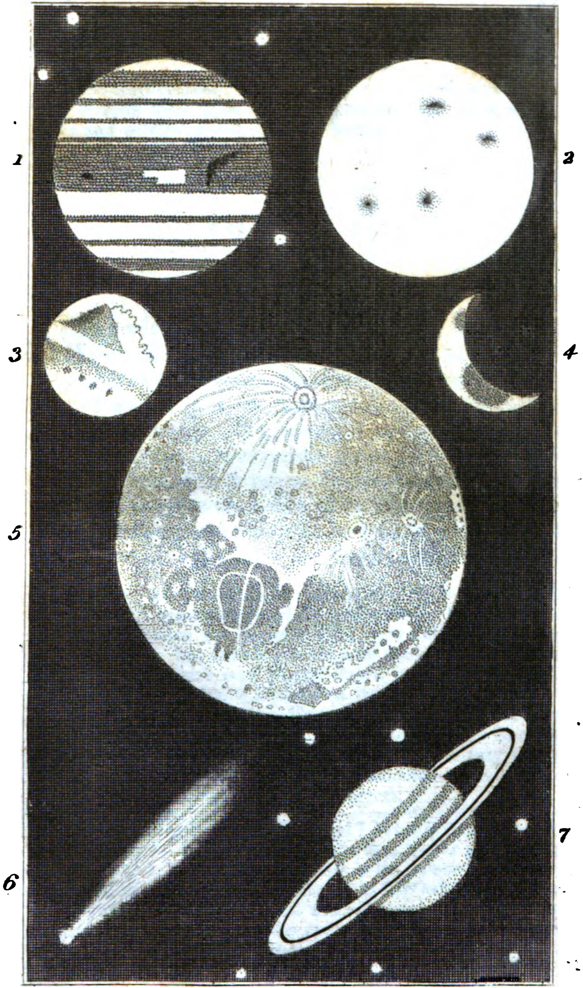
What its apparent diameter? What is its distance from the Earth? How is it found to be an opaque body? What occasions the inequality of light reflected from its surface? What is the height of its atmosphere?

What is Schroeter's estimate of the height of mountains and depth of cavities on the surface of the Moon? What other facts can you state?

page 18 Plate 1.



1 Jupiter; 2 Sun; 3 Mars; N. & S. S. Jocelyn Sc.
4 Venus; 5 Moon; 6 Comet; 7 Saturn;

be considered volcanic, and one of them in a state of eruption. The scenery there must be very romantic, and some of the rocks and precipices, tremendously terrific.

CHAPTER IV.

MARS.

Next without the orbit of the Earth, is the orbit of Mars. Hence it is called a *superior* planet. Its diameter is 4444 miles, its density 3 times the density of water, and its distance from the Sun, 144 millions of miles. It turns on its axis in 24½ hours, and performs a revolution round the Sun in 687 days, or less than 2 years. Its torrid zone, extends about 28 degrees each side of its Equator. It moves above 50 thousand miles the hour, and enjoys about half as much light from the Sun, as the Earth.

Mars has an uncommonly red appearance, which is occasioned by the great density of its atmosphere. This accounts for the mountains not being visible, as in the planets Venus and Mercury. But the accumulation of whiteness at the pole, from which the Sun's rays are withdrawn, is indicative of vicissitudes in seasons, similar to those on the Earth. See telescopic appearance of Mars, Plate i. Figure 3. Mars, in conjunction with the Sun, is 239 millions of miles distant; when in opposition only 49 millions of miles. Of course, it will vary from 9 seconds to 29 seconds, in its apparent diameter. The angle of its orbit with the Ecliptic is about 2 degrees.

Why is Mars called a *superior* planet? What is its magnitude? —its density?— its distance from the Sun?—the period of its rotation? and its hourly rate? What is the extent of its torrid zone, and its comparative amount of light? What is the color of Mars? and what its cause? and what its consequences? What variations are there in its polar appearances?—in its distance? —and in its apparent magnitude.

ASTEROIDS.

SINCE the nineteenth century commenced, FOUR very small planets have been discovered, between the orbits of Mars and Jupiter. Their names are Ceres, Pallas, Juno, and Vesta.

Their real magnitudes are not yet accurately ascertained; they are estimated from 80 miles, to 2000 miles, in diameter. Probably neither of them is 1500 miles in diameter. Their density is something more than twice the density of water. Their mean distances from the Sun, vary from 225 millions, to 266 millions of miles. The light enjoyed at them, about one ninth as great as at the earth. One performs its revolution in less than 4 years; another in 4 years and 4 months. Two perform their revolutions with only 1 day's variation; 4 years, 7 months, and 10 days, and 11 days. Two of the Asteroids have their orbits much more inclined to the Ecliptic, and comparatively much more eccentric, than other planets.

Their nodes, and their points of nearest approach to the Sun, being in the same general direction in the heavens, together with their apparent irregularities, have originated the hypothesis that they have once been a single planet. The great atmospheres of two are conjectured to have been derived from the Comet of 1770, the disappearance of which is supposed to be otherwise unaccountable. In the Tabular view, the largest estimate of two of them is from Schroeter, the smallest from Herschel.

When were the Asteriods discovered? What are their names? What their magnitudes?—densities?—distances from the Sun?—and periods of revolution?

What facts are supposed to favour the hypothesis, that they once constituted but one planet? What is thought of the atmospheres of two of them?

CHAPTER V.

JUPITER.

Receding from the Sun, we next arrive at Jupiter, the largest of the planets; with an apparent diameter of about 40 seconds, and a real diameter of more than 89 thousand miles. Its density is about 1¼ the density of water; it turns on its axis in less than 10 hours, and revolves round the Sun in less than 12 years, at the distance of 490 millions of miles. Compared with the Earth, it has nearly 14 hundred times as much bulk, and about 300 times as much matter. The velocity with which it turns on its axis, must occasion an apparent motion of the Sun and stars, to organs of vision like ours.

The inclination of Jupiter's orbit, to the plane of the Ecliptic, is very small; and the Sun is constantly vertical at its Equator, allowing no variety in the length of its days, and little vicissitudes in seasons. The amount of light enjoyed there, is about one twenty-fifth part of what is enjoyed at the earth.

Light diminishes, as the squares of the distance increase. Call the distance of the Earth from the Sun, one part in five, of the distance of Jupiter. The Asteroids are about three parts of this distance, and three times three are 9, therefore, they have one-ninth of the light of the Earth. Five times five are 25, therefore, as Jupiter is five such parts distant from the fountain of light, it has only one twenty-fifth part as much light by day as the Earth.

What is the apparent diameter of Jupiter? What is its real diameter? What is its density?—its distance from the Sun?—the time of its rotation? and of its revolution? How much more bulk than the Earth? and how much more matter? What effects result from the velocity of its rotation? What from a constantly vertical Sun at its equator? What amount of light does it enjoy?

At what rate does light diminish? How can you illustrate this?

The quick rotation of Jupiter on its axis, is connected with its being much flattened at its poles. Its disc, when seen through a telescope, is diversified with alternate streaks of light and shade called belts; as seen in Plate i. Figure 1. These vary their size and position so rapidly, as to lead to the opinion, that they are occasioned by clouds in its atmosphere, formed in regular strata by the velocity of its diurnal motion.

SATELLITES OF JUPITER.

Jupiter has four satellites or moons. Two of them are estimated as nearly the magnitude of the Earth, and two as larger. Their densities are like their primary. The times of their revolution vary from 1¾ days to 16½ days.

Three of them revolve so near the plane of the primary's orbit, as to eclipse the Sun, and to be eclipsed, to eyes, on Jupiter, at every revolution.

The fourth revolves without an eclipse one time in three. Galileo, when discovering them, by a telescope of his own invention, little more than two centuries ago, doubtless had no conception of the eminent utility to mankind, of that discovery. From their eclipses, longitude can be accurately computed, and the difficult problem, of the rate at which light moves, mathematically demonstrated. From the periods of their revolution, the density of Jupiter can be estimated, and the correctness

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Is Jupiter more spheroidal than the Earth? Why? What are seen on its disc? What is the supposed cause? How many satellites has Jupiter? What are their magnitudes?—densities?—distances from their primary? What eclipses result from their motions? By whom were they discovered? What advantages have resulted from their discovery?

of Kepler's rule, for computing the distances of the planets from the Sun, clearly proved.

The mean distance of Jupiter's satellites from their primary, and their periods of revolution, are as follows. The *first* is two hundred and sixty-six thousand miles distant, and revolves in one day and eighteen hours. The *second* is four hundred and twenty thousand miles distant, and revolves in three and a half days; the *third* and largest is six hundred and seventy thousand miles distant, and revolves in seven days; the *fourth* is more than a million of miles distant, and revolves in sixteen and a half days. The angles which their orbits make with the primary, as seen from the Earth in its mean distance from Jupiter, are from four minutes, to seventeen and a half minutes; about half the apparent diameter of the Moon's disc. Suppose an eclipse of one of these satellites, is accurately predicted to be seen in the meridian of Greenwich, England, precisely at twelve o'clock at noon, and an observer near Philadelphia, sees it precisely at seven o'clock in the morning, by a watch set to the meridian of that city, he then knows, that Philadelphia is 75 degrees west longitude from Greenwich, because the meridians of the two places, are found to vary five hours. Suppose an eclipse of one of these satellites, computed with perfect accuracy, if seen from the Sun. Now if the Earth were directly between the Sun and Jupiter, that eclipse would terminate eight minutes sooner than predicted; or if the Earth were exactly on the opposite side of the Sun from Jupiter, it would terminate eight minutes later than predicted. These facts would prove, that light coming across the whole diameter of the Earth's orbit, occupied sixteen minutes; and knowing that distance to be one hundred and ninety millions of miles, the velocity with which light moves, would be found to be nearly two hundred thousand miles the second.

CHAPTER VI.

SATURN.

Half a century ago, Saturn was the remotest planet from the Sun, which had been discovered;

How distant from the primary, and how long the period of the revolution of Jupiter's 1st satellite?—2d satellite?—3d satellite?—4th satellite? What angles do their orbits make as seen from the Earth? How can Longitude be learned by their eclipses? How the velocity with which light moves estimated?

and from its splendid appendages, it is still an object of intense interest, to the scientific observer. Its apparent mean diameter is 18 seconds; and its real diameter is 79 thousand miles. Its density is about half the density of water, making about one hundred times as much matter, and nearly one thousand times as much bulk in Saturn as in the Earth. Thus far the densities of planets diminish, as you recede from their centre of motion. Saturn turns on its axis in 10¼ hours; and requires almost 30 years to complete its revolution round the Sun, at the distance of 900 millions of miles, and moving 22 thousand miles the hour.

At its equator, it has more than 25 thousand days in one of its years; at its poles, but one day and one night. The orbit of Saturn inclines to the Ecliptic 2½ degrees, and its axis has an inclination to its orbit, which makes the Sun shine vertically 30 degrees on either side of its equator. It is more spheroidal than Jupiter, and receives about one ninetieth part of the light enjoyed at the Earth. Infinite wisdom and benevolence has, however, wonderfully compensated for this deficiency.

SATURN'S APPENDAGES.

Two remarkable rings, encircle Saturn at its equator. The outermost, is more than 200 thousand miles in diameter, and about 7 thousand miles in breadth, towards the planet. A space occurs be-

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What planet is next *without* the orbit of Jupiter? What is its apparent diameter?—its real diameter?—density? What is the period of its rotation?—revolution? What is its distance from the Sun?—its velocity the hour? How near the Ecliptic is it always seen? How broad its torrid zone? What amount of light? What remarkable appendages has Saturn? What is the diameter of the outermost ring?—its breadth?

Fig. 1.

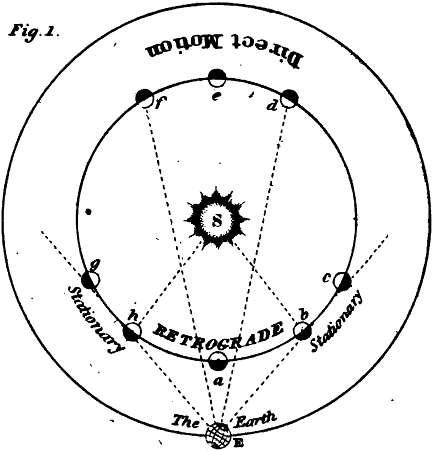
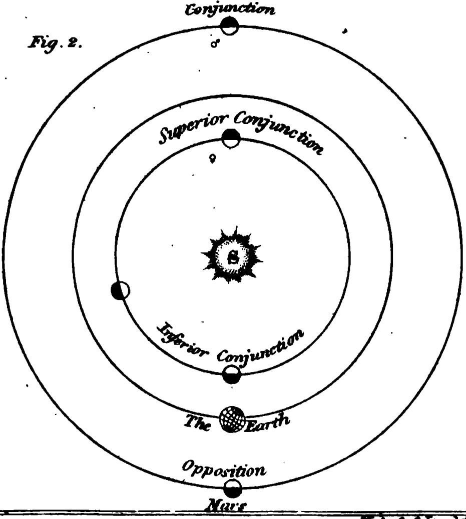


Fig. 2.



N. & S. S. Jocelyn

tween that and the innermost ring, of less than 8 thousand miles, and that second ring is nearly 20 thousand miles in breadth, leaving a space between it and Saturn, of something more than 30 thousand miles. They are rounded at their edges, and extend north and south, about 4500* miles, and are supposed to be equally dense with the planet, and to revolve around it in about 10½ hours.

Great inequalities are observable in different parts of the rings, which La Place considers as contributing to render their motions more stable than they would otherwise be.

Besides the rings, seven satellites attend Saturn. The nearest revolves in about 22½ hours, at about 47 thousand miles distance from the largest ring. The remotest is more than 2 millions of miles distant from the planet, and revolves in about 80 days. The other five, at intermediate distances and periods. Their magnitudes are various: from four times the magnitude of our Moon, to about the magnitude of the Earth; and their densities are like their primary.

An engraving of Saturn will be found on Plate i. Figure 7.

Organs of vision like ours, enjoying a cloudless winter evening sky in Saturn, would behold as splendid and magnificent a scene, as our imagination can well form in a physical universe. But such organs of vision there, would be unable to discern the Earth without a telescope. "There is not, perhaps," says Dr.

What is the breadth of the innermost rings? What is their supposed thickness? What is the period of their rotation?

What inequalities are discoverable in the rings? What is the utility of these inequalities?

How many satellites has Saturn? What is the period in which the nearest revolves? What is its distance from one ring? In what period does the most remote satellite revolve?—at what distance? What are their magnitudes?—densities?

How would the evening sky appear in Saturn.

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* Herschel, as quoted by Bonnycastle?

Herschel, "another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn; a magnificent globe, encompassed by a stupendous double ring; attended by seven satellites; ornamented with equatorial belts; compressed at the poles; turning on its axis; mutually eclipsing its rings and satellites, and eclipsed by them; the most distant of the rings also turning upon its axis, and the same taking place with the remotest of the satellites; all the parts of the system of Saturn occasionally reflecting light to each other; the rings and the moons illuminating the nights of the Saturnian; the globe and the satellites enlightening the dark parts of the rings; and the planet and rings throwing back the Sun's beams upon the moons, when they are deprived of them, at the line of their conjunction."

CHAPTER VII.

HERSCHEL.

In 1781, a new planet was discovered by Herschel, whose name it deservedly bears. It is like a star of the sixth magnitude to the naked eye, and seems slightly tinged with blue. Its apparent diameter is only 4 seconds, and its real diameter 35 thousand miles. Its density is equal to water. The time of its rotation unknown, but its period of revolution round the Sun, is almost 84 years, at the vast distance of 1800 millions of miles. It moves at the rate of about 15 thousand miles an hour, and receives from the Sun only one three hundred and sixtieth part of the light the Earth enjoys.

It has before been intimated, that light and caloric seem not to be governed by the same laws. It cannot therefore be known, what amount of heat and fertility exist in any other planet but

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When was Herschel discovered? What is its apparent diameter?—real diameter?—density?—period of rotation?—revolution?—rate the hour?—distance from the Sun?—comparative light?

Are light and caloric governed by the same laws? What hypothesis respecting life in other planets is here introduced?

the Earth. Life, adapted to its location, and analogous to vegetable, animal, and intellectual life, on the Earth; though entirely diverse in most of its circumstances from life here; may exist in other planets, and be immeasureably diffused in the material universe.

HERSCHEL'S SATELLITES.

Six satellites attend the protracted journey of this most distant planet which has yet been discovered. The nearest, is about as remote from Herschel, as the Moon from the Earth, and performs its revolution in between five and six days. The most distant is 1½ millions of miles from its primary, and is 107 days in performing a revolution. Their densities are supposed to be like that of Herschel; but their orbits, unlike the orbits of all the other satellites, are nearly at right angles with the orbit of the primary, as though our Moon were to revolve from south east to north west, round the Earth.

Doubtless, these satellites exhibit the Creator's wisdom and benevolence, like his other works. The fact, that they may be revolving in a way to have some of them always above the horizon, and always half enlightened as seen at Herschel, might create more admiration in us, if we more minutely knew their circumstances.

The scale on the frontispiece, divided into 200 parts, gives about the proportionate distances of planets, without the high enumeration of figures. Perhaps other planets, and some more distant than these, may yet be discovered.

Tabular views of the solar system and of the satellites are subjoined. For the greater densities of the Earth and the Moon, than has commonly been assigned them, we have the authority of Playfair, Cavendish, and Bakewell.

How many satellites attend Herschel? What are the extremes of their distances? What are their periods of revolution? How does their revolution differ from other satellites?

Where Tables are introduced in this work, the captions of the different columns, will suggest appropriate questions to Instructers and others.

TABULAR VIEW OF THE SUN AND PLANETS.

Names.	Character.	Mean apparent diameters	Diameters in miles.	Densities, water being one.	Mean distance fr. sun in mil. of mls.	Periods of rotation on their axes.	Periods of revolution round the sun.	Hourly rate of motion in 1000 miles.	Incl. of th'r axes to plane of their orbits.	Incl. of their orbits to the ecliptic.	Comp. light, light on th'earth being 1.	Eccen. of their orbits in mill. of miles.
						d. h.	y. d.					
The Sun	☉	32′ 1″	886,246	1⅖		25 14			82° 44′			
Mercury	☿	10	3,224	9	37	24	88	108		7°	7	7½
Venus	♀	38	8,210	6	68	23½	224	84	15	3½	2	½
The Earth	⊕		7,938	5	95	1	365¼	68	66 32			1½
The Moon	☽	31 30	2,180	5	95	27 8	365¼	2	88 17	5 9′		
Mars	♂	17	4,444	3	144	24½	686	54	62	2	½	13
Vesta	⚶	1½	238	2	225	un-	3 60	42	unk'n.	7	1/6	20½
Juno	⚵	3	1,425	2	252	kn'wn.	4 128	41	"	13	1/9	63
Ceres	⚳	1 6	163 2,024	2	265	" "	4 220½	40	"	10½	1/9	21½
Pallas	⚴	0½ 6½	80 2,099	2	266	"	4 221½	40	"	34½	1/8	65
Jupiter	♃	39	89,170	1¼	490	10	11 314	30	90	1¼	1/25	23½
Saturn	♄	18	79,042	½	900	10¼	29 162	22	60	2½	1/90	51
Herschel	♅	4	35,112	1	1800	unk'n.	83 305	15	unk'n.	½	1/360	86

JUPITER'S SATELLITES.

No. of the satellites reckoning from the primary.	Period of revolution on its axis and round its primary.	Mean distance from its primary in thousands of miles.	Mean apparent distance.
	d. h. m.		
First	1 18 28	266,000	3′ 55″
Second	3 13 17	425,000	5 14
Third	7 3 59	676,000	8 58
Fourth	16 18 6	1,180,000	17 30

SATURN'S SATELLITES.

First	0 22 37	107,000	29
Second	1 8 53	135,000	37
Third	1 21 18	170,000	43
Fourth	2 17 41	217,000	56
Fifth	4 12 25	303,000	1 18
Sixth	15 22 41	704,000	3 10
Seventh	79 7 48	2,050,000	8 42

HERSCHEL'S SATELLITES.

First	5 21 25	230,000	25
Second	8 16 57	298,000	33
Third	10 23 2	348,000	38
Fourth	13 10 56	399,000	44
Fifth	38 1 48	746,000	1 28
Sixth	107 16 39	1,597,000	2 56

There is great inequality, in the amount of light emitted by different satellites, of the same primary. Those planets and satellites most remote from the Sun, may, of course, be expected to reflect light, in a less vivid and paler manner than those more near.

CHAPTER VIII.

COMETS.

The ancients considered comets as supernatural and ominous appearances in the heavens. Modern discoveries in Astronomy, have proved, that comets are bodies governed by kindred laws, with the planets. But unlike planets, all of which revolve from west to east round the Sun, comets revolve in every direction, and in orbits so extremely elliptical, that they continually intersect each other, and the orbits of the planets. Science, while it liberates from the fears of superstition, leads to the conclusion, that it is *possible* for a comet to approach inconveniently and fatally near, to the habitation of man.* The number of comets is supposed to be nearly 500; the elements of only 100 of which have been computed. Commonly they have a small solid nucleus, surrounded with aqueous vapor; and usually accompanied by a luminous transparent train, always in an opposite direction from the Sun.

Newton supposed that the heads of the comets were exceedingly dense matter, that might be raised to a heat 2000 times greater than red hot iron, and the train was vapor or steam

What were the opinions of the ancients respecting comets? By what laws are they governed? How do their orbits and motions differ from those of planets? What event is named as *possible?* If a comet revolved exactly in the plane of the Ecliptic, how many chances to one against a contact with the Earth? How many comets are supposed to belong to our system? By what are they attended?

What hypotheses have been started respecting their heads? —and their luminous trains?

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* If a comet revolved in the plane of the Ecliptic, there would be more than 35,000 chances each revolution *against* its coming in contact with the Earth, to one chance that it would touch our planet. But as no comet is known to revolve exactly in the plane of the Ecliptic, the danger is incalculably less.

thus produced. These opinions cannot be defended. Others have supposed, that the nucleus of the comet is transparent, and rays of the Sun, tinged by passing through it, become visible. This would account for their tails being always opposite to the Sun. But a recent and still more probable theory is, that the tails are the electric fluid, passing off like the aurora borealis.

THE magnitudes of the comets are various; and the periods of their revolution, are from 40 months to more than 575 years.

The solid nucleus of the Comet of 1807, was estimated at 583 miles in diameter, while it was surrounded with a mass of aqueous vapor, supposed to be nearly 200 thousand miles in diameter, and attended by a train more than 9 millions of miles in length. The Comet of 1811 had a head very imperfectly defined, and a tail 80 millions of miles in length, as seen in the northern hemisphere, and still more as seen in the southern hemisphere. The tails of some comets have subtended an arc of 60, or 90, or even 104, degrees in the heavens. The splendid Comet of 1744, known in the traditions of New-England as the great blazing star, was supposed to have a head as large as Jupiter. Comets have had an *apparent* magnitude from that of Venus, to six times that magnitude, and a few have appeared nearly the size of the Moon, though with a more dim and dead light. Of the 98 comets, the elements of which have been computed, 24 have their perihelion, or nearest approach to the Sun, within the orbit of Mercury; 33 between the orbits of Mercury and Venus; 21 between Venus and the Earth; 16 between the Earth and Mars; 3 between Mars and Ceres; and 1 between Ceres and Jupiter. The Comet of 1811 did not approach at its perihelion, nearer than 95 millions of miles from the Sun, and was more than 140 millions distant from the Earth. The Comet of 1680 approaches within 300 thousand miles of the Sun, and recedes 7 times as distant as Herschel. At its perihelion, it moves with the astonishing velocity of more than 800 thousand miles the hour; at its aphelion less than two miles the hour. The correctness, of the estimated elements, of a very few only of the comets, has been proved by the actual appearance of these bodies, when predicted to appear. "The immense distances to which these bodies are carried, and the

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What is said of the magnitudes, and periods of revolution of some? What facts are given respecting the comets of 1811?—of 1744?—of 1680?

comparatively small portions of their orbits which come under our inspection, as well as their imperfect undefined appearance in the telescope, and the great interval of time which elapses between their reappearance, are impediments which nothing but time and the most accurate and diligent observations can remove; and therefore many ages must necessarily elapse before the theory of comets can be brought to perfection. Every thing, however, that ingenuity and industry can accomplish, may be expected from astronomers of the present day, whose diligence and accuracy have led them to many interesting discoveries, and to whose future perseverance we may confidently look for others equally important." *Bonnycastle.*

CHAPTER IX.*

THE FIXED STARS.

FROM the evening of the sixth day of the creation to the present hour, the starry heavens must have been objects of intense interest, to the inquisitive mind of man. The ancients considered them luminous points in a vast concave sphere, which was revolving from east to west round the Earth in 24 hours. A slight observation convinced them that some, which appeared to be stars, changed their positions among the others, or wandered; they were therefore called planets, or wanderers. Those keeping their positions from month to month were called FIXED STARS. The number of these, visible to the naked eye, in one hemisphere, is about 1000. An equal number may be seen in the opposite hemisphere.

How were the starry heavens anciently regarded? Why were some *apparent stars* called planets? About how many fixed stars are visible to the unaided eye?

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* If any Instructer, thinks the subject of the Fixed Stars should be taught later in the course, this chapter can be deferred, and resumed afterwards.

Indistinct glances at the stars, often leave the impression that several thousands may be seen at once. But minute and careful surveys will correct this error. The *Fixed Stars* are easily distinguished from the steady light of the planets, by their scintillation or twinkling.

It is highly probable, that grouping the STARS into constellations, was done by the ancients, partly for the purpose of perpetuating important events in sacred and profane history, and partly to subserve their convenience of classification. Some of these constellations are very ancient, as their names are found in the most ancient writings extant. Perhaps the Ship and the Raven are of Hebrew origin; while Hercules, Andromeda and others, undoubtedly originated with the Greeks.

Patient surveys of the number and positions of the Fixed Stars, have been made by Hipparchus, Ptolemy, Tycho Brahe, Hevelius, and Flamstead, affording interesting opportunities of comparing ancient and modern observations.

The ancient constellations amounted to but 48. Modern catalogues have arisen to between 90 and 100. I shall use a list containing 93 constellations, where the number of stars in and near each, is given according to Flamstead. Seven or eight hundred stars are inserted, too small to be seen without a telescope, leaving from 2000 to 2200 visible to the naked eye. The stars visible without a telescope, are divided into six classes. The largest, are called stars of the 1st magnitude; the least, stars of the 6th magnitude. There are about 17 of the 1st magnitude, 50 of the 2nd magnitude,

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Why are we liable to misjudge respecting their number? How may they be distinguished from planets?

Why have the stars been grouped? To what nations are some of them obviously to be traced? Who have minutely surveyed them? How many ancient constellations?—modern ones? Into how many classes are the stars divided?

150 of the 3rd magnitude, and the remainder are of the 4th, 5th and 6th magnitudes.

A LIST OF THE CONSTELLATIONS.

ZODIACAL CONSTELLATIONS.

Names of the Constellations.	*No. of Stars.*	*Principal Stars.*
Aries, The Ram	66	Arietis 2
Taurus, The Bull	141	Aldebaran 1 The Pleiades The Hyades
Gemini, The Twins	85	Castor 1 Pollux 2
Cancer, The Crab	83	
Leo, The Lion	95	Regulus 1 or Lion's Heart
Virgo, The Virgin	110	Spica Virginis 1 Vendemiatrix 2
Libra, The Balance	51	
Scorpio, The Scorpion	44	Antares 1
Sagittarius, The Archer	69	
Capricornus, The Goat	51	
Aquarius, The Water-bearer	108	Scheat 3
Pisces, The Fishes	113	

THE NORTHERN CONSTELLATIONS.

Names of the Constellations.	*No. of Stars.*	*Principal Stars.*
Ursa Minor, The Little Bear	24	Pole Star 2
Ursa Major, The Great Bear	87	Dubhe 1
Cassiopeia, Lady in the Chair	55	Schedar 3
Perseus, Perseus	59	Algenib 2
Auriga, The Wagoner	66	Capella 1
Boötes, The Bear Driver	54	Arcturus 1
Draco, The Dragon	80	Rastaben 3

How many constellations are there in the Zodiac?

THE NORTHERN CONSTELLATIONS (*continued.*)

Names of the Constellations.	*No. of Stars.*	*Principal Stars.*
Cepheus - - - -	35	Alderamin 3
Canes Venatici, The Greyhounds	25	
Cor Caroli, Charles' Crown	3	
Triangulum, The Triangle	16	
Triangulum Minus, The Lesser Triangle	5	
Musca, The Bee	6	
Lynx - - - -	44	
Leo Minor, The Little Lion	24	
Coma Berenicus, Berenice's Hair	40	
Camelopardalus, The Camelopard	58	
Mons Menelaus - -	11	
Corona Borealis, The Northern Crown	21	
Serpens, The Serpent	50	
Scutum Sobieski, The Shield of Sobieski	8	
Hercules cum Ramo et Carbo, Hercules kneeling.	113	Ras Algiatha 3
Serpens sive Ophiuchus, Serpentarius	68	Ras Alhagus 3
Taurus Poniatowski	7	
Vulpecula et Anser, The Fox and Goose	37	
Lyra, The Harp	22	Vega 1
Sagitta, The Arrow	18	
Aquila, The Eagle	40	Altair 2
Delphinus, The Dolphin	18	
Cygnus, The Swan	73	Deneb Adaga 1
Equuleus, The Little Horse	10	
Lacerta, The Lizard	16	
Pegasus, The Flying Horse	85	Markab 2
Andromeda - - -	66	Almaac 2

How many constellations are there in the northern hemisphere?

THE SOUTHERN CONSTELLATIONS.

Names of the Constellations.	*No. of Stars.*	*Principal Stars.*
Phœnix, Phœnix	13	
Officina Sculptoris, The Sculptor's Shop	12	
Eridanus, The River	76	Achernar 1
Hydrus, The Hydra	10	
Cetus, The Whale	80	Menkar 2
Fornax Chernica, The Furnace	14	
Horologium, The Clock	12	
Reticulus Rhomboidalis, The Rhomboidal Net	10	
Xiphias, The Sword Fish	7	
Cœla Sculptoris, or Praxiteles, The Engraver's Tool	16	
Lepus, The Hare	19	
Columbia Noachi, Noah's Dove	10	
Orion, - - - - -	78	Betelgeuse 1
Argo Navis, The Ship Argo	50	Canopus 1
Canis Major, The Great Dog	30	Sirius 1
Equuleus Pictonius, The Painter's Easel	8	
Monoceros, The Unicorn	31	
Canis Minor, The Little Dog	14	
Chamælon, Chameleon	10	
Pixis Nautica, the Mariner's Compass	4	
Piscis Volans, The Flying Fish	8	
Hydra - - - -	60	Cor. Hydræ 1.
Sextans, The Sextant	4	
Machina Pneumatica, The Air Pump	3	
Crater, the Cup	31	Alkes 3
Corvus, The Crow	9	Algorab 3
Crux, The Cross	6	Crucis 1
Musca, The Bee	4	
Apus, The Bird of Paradise	11	
Circinus, The Compasses	4	
Centaurus, The Centaur	36	
Lupus, The Wolf	24	

THE SOUTHERN CONSTELLATIONS (*continued.*)

Names of the Constellations.	*No. of Stars*	*Principal Stars.*
Quadra Euclidis, Euclid's Square	12	
Triangulum Australe, Southern Triangle	5	
Ara, The Altar	9	
Telescopium, The Telescope	9	
Corona Australis, Southern Crown	12	
Pavo, The Peacock	14	
Indus, The Indian	12	
Microscopium, The Microscope	10	
Octaus Hadleinaus, Hadley's Quadrant	43	
Crus, The Crane	14	
Toucan, American Goose	9	
Piscis Australis, The Southern Fish	20	Fomalhaut 1

The distances of the fixed stars deserve consideration; for though the exact distance of Sirius, supposed to be the nearest, cannot be given, it can be proved that it *must be more* than 200 thousand times as distant as the Sun.

That the fixed stars are very distant, is obvious from these facts. Seen through a telescope of 200 magnifying power, they seem less than to the naked eye. Increase the magnifying power of the glass, they are still but luminous points, while the planets disclose broad discs, which can be measured; and satellites before invisible. Again, the Earth's place the 23rd of September, is the whole diameter of its orbit distant from where it was the 20th of March, but the nearest fixed star is too remote to have that 190 millions of miles, make any *apparent* change in its direction, and such change would be perceptible, if the star were not more than 200 thousand times the distance of the Sun.

How many constellations in the southern hemisphere? What star is supposed to be the nearest? How distant must it be? What proof can you give, that the stars are 200 thousand times more distant than the Sun?

The conclusion becomes unavoidable, that the fixed stars shine with unborrowed light; that they must be vast luminous bodies like our Sun; and that they may be centres to retinues of planets and comets, as numerous, and as full of beauty and of being, as those in attendance on our Sun.

The stars in each constellation which have not specific names, are called by the names of letters in the Greek alphabet; the largest Alpha, the next Beta, the third Gamma, &c. If there are more stars in a constellation than Greek letters, Italic letters are used. Alpha in one constellation, may be of a different magnitude from Alpha in another.

While there is a variety of hues in the light emitted by the fixed stars, there are variations of magnitude in some of them. Dr. Herschel concludes this variation is occasioned by inequalities of luminous matter on their sides; and that their rotation, on their axis, presents at one time the most luminous side, at another the least luminous.

One instance will be here introduced. Mr. Goodrick discovered that the star Beta in the constellation Lyra, is subject to the following *periodical variation*. It completes all its phases in 12 days and 19 hours, during which time it undergoes the following changes. 1. It is of the third magnitude for about 2 days. 2. It diminshes 1¼ days. 3. It is between the fourth and fifth magnitudes, for less than a day. 4. It increases about 2 days. 5. It is of the third magnitude for about 3 days. 6. It diminishes in about 1 day. 7. It is something larger than the fourth magnitude for a little less than a day. 8. It increases in about one day and three quarters to the first, and so completes a whole period. See Phil. Trans. 1785. Irregular variations, in the magnitudes of some stars, have been observed.

Many of the stars, which to the unassisted eye appear single, are proved by the telescope to be

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What conclusion *must we* form respecting them? What seems probable?

What use have astronomers made of Greek and Italic letters?

What is supposed to be the cause of apparent varying magnitudes in some of them?

double stars. Not apparently double, because one star is seen almost in the same line with another, though two or three times as distant, but double, because they are near to each other, and are revolving round a central point between them, in periods of three, five, ten, or fifteen centuries. Observations made for 40 years by Dr. Herschel, have established these facts.

Why may not these be centres of binary systems, where planets may be illuminated, and warmed, and fertilized by two Suns? Dr. Herschel has formed a catalogue of more than 400 such double stars; a few of which will be given.

German astronomers have much increased the catalogue of double stars.

Two large stars in the constellation Orion (known in popular language as the Yard and L.) are double stars; unequal in their magnitudes and varying in their colors. The stars *Alpha*, *Beta*, and *Delta*, in Hercules, are double stars. The stars of the first magnitude, *Aldebaran* in Taurus, and *Castor* in Gemini, are double stars. The north polar star is double, consisting of a larger star, white in color, and a smaller star, red in its hue.

Other remarkable phenomena in the heavens, must not be overlooked. There are treble, quadruple, and quintuple stars. Three, four, five, and sometimes more, appear revolving round a common centre among themselves, forming systems of material worlds, variegated to an extent beyond what the imagination of man can conceive.

Such stars are found in Ursa Major, Canis Major, Orion, and others of the constellations. A still more remarkable appearance has been discovered in Orion. Its discoverer called it a luminous circular window, of more than 100 millions of miles

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What is said of double stars and the period of their revolution?

How many double stars have been discovered? Where may some of them be found?

What other remarkable phenomena deserve to be noticed?

What is said to be visible, with a telescope, in Orion?

in diameter, through which, we catch a glimpse of a more brilliant universe beyond. Where that bright portal leads, and what are the material glories which faintly gleam on mortal vision, who can tell?

Already by the aid of the telescope, our thoughts are contemplating many thousands of stars, each one of which must be a Sun. But the whiteness of the Galaxy, when viewed by Dr. Herschel's large telescope, is resolved into stars so numerous, that probably more than 10 millions belong to that single zone of suns, of which our Sun is supposed to make one.

They are thought to be in motion round their common centre of gravity, and that this accounts for the motion of our system towards the constellation Hercules. Extended as the material universe thus seems, we must not stop our investigations here. Twenty-five hundred other fields of light in the heavens called nebulae, have been counted. It is a plausible theory, that each of these is the nearer part of another zone of suns, having its remotest parts too distant for telescopes to reach. And if 25 thousand millions of suns belong to these zones, are even 25 hundred ZONES OF SYSTEMS, the whole of creation?

There is one more topic respecting the fixed stars, which may not be omitted. New stars are shining in our sky, and others which once adorned it, have disappeared, under circumstances not to be satisfactorily accounted for, but in supposing the Creator's power still employed both in kindling and extinguishing suns, in his universe.

An extract from the Surrey Lectures, of the late eminent physician Dr. Good, will give light and emphasis to this thought.

What occasions the whiteness of the Galaxy? How many suns are supposed to exist in that one zone?

What hypothesis is started respecting other zones of suns? Can we set bounds to creation?

What evidence exists that new suns are created and other suns extinguished from century to century?

What distinguished authority can be quoted, in confirmation of the opinion, that stars are disappearing?

" But worlds and systems of worlds are not only perpetually creating, they are also perpetually diminishing and disappearing. It is an extraordinary fact, that within the period of the last century, not less than thirteen stars in different constellations, none of them below the sixth magnitude, seem totally to have perished; forty to have changed their magnitude, by becoming either much larger or much smaller; and ten new stars to have supplied the place of those that are lost. Some of these changes may perhaps be accounted for by supposing a proper motion in the solar or sidereal systems, by which the relative positions of several of the heavenly bodies have varied. But this explanation, though it may apply to several of the cases, will by no means apply to all of them; in many instances it is unquestionable, that the stars themselves, the supposed habitations of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, and to which they may have given light and fructifying seasons, as the Sun gives light and fruitfulness to the Earth, have utterly vanished, and the spots which they occupied in the heavens have become blanks. What has befallen other systems will assuredly befal our own. Of the time and the manner we know nothing, but the fact is incontrovertible; it is foretold by revelation, it is inscribed in the heavens, it is felt throughout the Earth. Such is the awful and daily text; what then ought to be the comment?"

CHAPTER X.

LATITUDE AND LONGITUDE, TERRESTRIAL AND CELESTIAL.

The humble, but interesting and useful topics of Latitude and Longitude, require to be discussed. The rotation of the Earth is on an imaginary line, called its axis, the extremities of which are called its poles. A great circle round the Earth, at an *equal* distance from either pole, is on that account called its *Equator*. Lines drawn parallel to this, on either side, are called parallels of Latitude,

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How is *terrestrial* Latitude reckoned? How *terrestrial* Longitude?

because Latitude is reckoned across them to the poles, one quarter of a circle, or 90°. The Earth being spheroidal, or flattened at its poles, occasions the first degree of Latitude to be a trifle shorter than the next, and that, shorter than the third. A meridian is a direct line, passing from one pole to the other. Wherever that line is vertical, or directly over head, it will be *mid*-day when the Sun is in it. The common meridian for computing Longitude is that of Greenwich, England. Degrees of Longitude at the Equator, from the spheroidal figure of the Earth, will be a trifle longer than the first degree of Latitude. They will however diminish in their length, if computed in miles, as you approach the poles, till they terminate in a point. Terrestrial Longitude is reckoned half round the globe, or 180 degrees east and west.

In the heavens there is a great circle, where the Sun makes its apparent annual path, but which is the real orbit of the Earth around the Sun. This is called the *Ecliptic*; because all the eclipses occur when the Moon is near this circle, at the change, or full. It makes an angle of 23° 28″ with the Equator. Imaginary lines crossing the Ecliptic at right angles, as the meridians cross the Equator, are called secondaries to the Ecliptic, and terminate in points 23° 28″ from the points opposite to the poles of the Earth. These are called the poles of the Ecliptic. Here we may mark the difference between *terrestrial* Latitude, which is reckoned from the Equator to the poles; and *celestial* Latitude, which is reckoned from the Ecliptic, to the poles of the Ecliptic. When Latitude on Earth is

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What is the comparative length of degrees of Latitude and Longitude? What is the Ecliptic? How is *celestial* Latitude reckoned?

given, it is reckoned from the Equator; when the Latitude of stars or comets is given, it is their distance from the Ecliptic. *Celestial* Longitude is likewise different from *terrestrial*. Instead of being reckoned from a given meridian, it commences at the point among the stars in which the Sun appears at the vernal equinox, the 20th of March, or the beginning of the sign Aries. Besides, it is reckoned only *east*, and that quite round the heavens, making 360°. The longitude of celestial bodies is, therefore, always to be reckoned by their distance east of the Sun's place at the vernal equinox. This varies a trifle each year, owing to the precession of the equinoxes, the cause of which will be discussed in a future chapter, but the consequences of which, are a gradual change in the longitude of the stars, amounting in 26 thousand years, to a whole revolution. After such a long period, the Sun would return again at the vernal equinox, to the same point among the stars.

When the names were given to the constellations of the Zodiac, more than 2000 years since, the Sun at the vernal equinox was doubtless at the beginning of the constellation Aries, the signs and constellations being then together. At the vernal equinox now, the Sun is in the *constellation* Pisces, though that point is called the beginning of the *sign* Aries.

The horizon is another great circle. The *sensible horizon* is where our vision is bounded by the apparent meeting of the air, and the land, or water. The *rational horizon* embraces an entire hemisphere, having the *zenith*, or point directly

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How, *celestial* Longitude? How long a period is required for the precession of the Equinoxes?

How long since the signs and constellations of [illegible] were together?

What is the horizon?—the zenith?—the nadir?

over our heads for its pole, and the opposite point called *nadir*, a corresponding pole in the opposite hemisphere.

In Astronomy, this distinction is of minor importance.

It will be at once obvious, that the horizon varies with the position of the observer. A correct knowledge of the true places of the heavenly bodies, is of great utility in fixing the Latitude and Longitude of places on land, and incalculably important at sea. There, where winds and waves, rocks and shoals, conspire to jeopardize property and life, it is indispensable to safety, that the mariner should be able, by an observation of the heavenly bodies, to know his true place.

The Parliament of England felt the importance and difficulty of this subject to such a degree, that there was once a reward of twenty thousand pounds sterling offered, for the best method of determining Longitude at sea, which should be invented or discovered within a given time.

A very brief statement, how Latitude and Longitude can be ascertained, may not be uninteresting or unprofitable here, though a full discussion of the subject belongs to Navigation.

When the Sun is at the equinoxes, where it is the 20th of March, or the 23d of September, let a Quadrant be used at noon, to determine how high the Sun appears above the horizon. If found to be 48°, (which is called its *altitude*,) above the horizon, subtract the 48°, from 90°, the whole number of degrees between the horizon and the

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Where is a knowledge of Latitude and Longitude of most importance?

What evidence has been given that the English parliament consider this subject important?

How may Latitude be reckoned from the Sun's place?—from a star's place?

zenith, or point directly over your head, and the difference will be 42°, which is the Latitude of the place where the observation is taken. But if an observation were taken at the same place the 20th of June, the Sun's altitude would be 71° 28''; from which subtract 23° 28'', for the Sun then is north of the Equator, and you have 48° remaining, which you will use as in the other case. Latitude may be taken at night from any star, whose place is correctly known. Suppose an observation of the north polar star were taken, and found to be 40° above the horizon as at Philadelphia; then the Latitude would be 40° north.

To ascertain Longitude at sea, is attended with much more difficulty. Nautical tables, which give the Moon's true place among the stars, for every day and every three hours in the year, afford the practical navigator his surest method of determining his Longitude.

"As the exact situation of the Moon in her orbit, and her distance from the Ecliptic, are of infinite utility to navigators, for the purpose of ascertaining the Longitude at sea, her position, in respect to the nine most remarkable stars situate near the Ecliptic, is calculated for every three hours, and given in the Nautical Almanack. The nine stars are, *a*, in Aries; Aldebaran, in the eye of Taurus; Pollux, one of the stars in Gemini; Regulus, the heart of Leo; Spica Virginis, in Virgo; Antares, in Scorpio; *a*, in Aquila or the Eagle; Formalhaut, in Pisces Australis, the Southern Fish; and *a*, in Pegasus."

Picquot.

If rumor be true, that the Admiralty Board of England have in their possession a watch, called a chronometer, which has not varied a second in 17 months, and if that would keep time with equal accuracy at sea, it would be invaluable for estimating Longitude. For illustration: let that chronometer be set to Greenwich time, and let the mariner carrying it, keep another watch regulated to the time of the Sun's being in the meridian.

How can Longitude be estimated at sea?

How is Longitude found by a chronometer?

For every 15 degrees he sails west, his chronometer will be one hour earlier than the other watch. When he arrived at Philadelphia they would vary 5 hours, which being multiplied by 15 would give 75° Longitude west from Greenwich.

CHAPTER XI.

THE MOON'S MONTHS AND PHASES.

THE time required for the Moon to revolve from *west* to *east*, round the Earth, is called a *month*. The actual revolution of the Moon is in 27⅓ days; while it requires 29 days, 12 hours, and about 44 minutes between one change and another, of the Moon. This arises from the annual motion of the Earth, in its orbit round the Sun.

For illustrating this subject, use Plate iii. Figure 1. Let S represent the Sun, and T the Earth in a part of its orbit, Q, T, L. Let E be the position of the Moon. If the Earth had no motion, the Moon would move round in its orbit, E, F, G, &c., into the position of E again, in 27 days, 7 hours, 43 minutes; but while the Moon is describing its journey, the Earth is passing through nearly one twelfth part of its orbit. This the Moon must also describe, before the two bodies can come again into the same position they before held, with respect to the Sun. The time required to do this, added to the 27⅓ days, makes more than 29½ days.

THE PHASES OF THE MOON.

THE Moon is an *opaque*, or dark body, like the Earth, receiving from the Sun the light it gives to us. Of course, it will be *invisible;* its disc *partially* or *fully* illuminated, according as its enlightened hemisphere is turned *from*, or *towards* the Earth.

From what is the word *month* derived? What is the period in which the Moon revolves round the Earth?—from one change to another? Why do these periods differ?

How do you illustrate this from Plate iii. Figure 1?

How is it known that the Moon is an opaque body? What illustrations of this may be given?

In Plate iii. Figure 1, suppose A, B, C, D, E, &c., to represent the Moon in different parts of its orbit round the Earth, in which, one half is constantly enlightened and would so appear as seen from the Sun; then will the *enlightened parts* of the *outside* figures, represent the appearance of the Moon, as seen from the Earth.

When the Moon is at E, *no part* of its enlightened side *is visible on the Earth.* It is then *new Moon*, or *change.* And the Moon being *in a line between* the Sun and the Earth, they are said to be in *conjunction.*

The outside figure, opposite to E, is wholly dark, to show that the Moon is invisible at the *change.*

The whole illuminated hemisphere at A, is turned to the Earth, and this is called *full Moon;* and the Earth being between the Sun and the Moon, they are said to be in *opposition.*

When at F, a small part only will be seen from the Earth, and that will appear *horned;* at G, one half of the enlightened hemisphere is visible; it is then said to be in *quadrature.*

At H, three-fourths of the disc appears illuminated, when it is called *gibbous.* The eight positions, in which the Moon is seen in this diagram are called octants. The *change* and *full* are sometimes called *syzygies.*

The horns of the Moon directly after the change, will be turned to the east, after the last quadrature they will be turned to the west. The Moon turning once on its axis, while revolving once round its primary, will allow organs of vision like ours, if located in the centre of its hemisphere turned towards the Earth, to behold a luminary 13 times as large as our full Moon, directly over the head, passing through all the vicissitudes of the Moon's phases in 29½ days; but at periods

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When is the Moon said to *change?*—to be *horned?*—to be in *quadrature?*—to be *gibbous?*—to be *full?*

How would the Earth appear to organs of vision like ours if beheld from the Moon?

opposite to those of the Moon seen from the Earth. And it is reflected light from a gibbous primary which renders the dark part of this satellite visible when *horned*, directly after, or immediately before the change. Moving in its orbit to the east, the Moon comes to the meridian about 50 minutes later each evening.

CHAPTER XII.

ECLIPSES.

Where their causes are unknown, superstitious terrors, perhaps, always attend eclipses. Eclipse, in Astronomy, means a temporary deprivation of light, and is rarely used, but when applied to the Sun and Moon.

In describing eclipses of these luminaries, their discs are divided into twelve parts, called digits. The proportion of a luminary obscured, in a partial eclipse, is designated by the number of digits said to be eclipsed. If 8 digits are eclipsed, then two-thirds of the luminary will be obscured.

LUNAR ECLIPSES.

An eclipse of the Moon is occasioned by the interposition of the Earth, between the Sun and Moon, and consequently, it must occur when the Moon is in *opposition* to the Sun, or at the *full Moon*; as seen in Plate iv. Figure 1.

If the plane of the Moon's orbit coincided with the Ecliptic, there would be a lunar eclipse at every *full Moon*, and a solar eclipse at every *change*.

How has superstition regarded Eclipses? What is an Eclipse?

Into how many parts are the discs of luminaries divided? What are they called?

What occasions an eclipse of the Moon? What are the Moon's nodes?

Fig. 1.

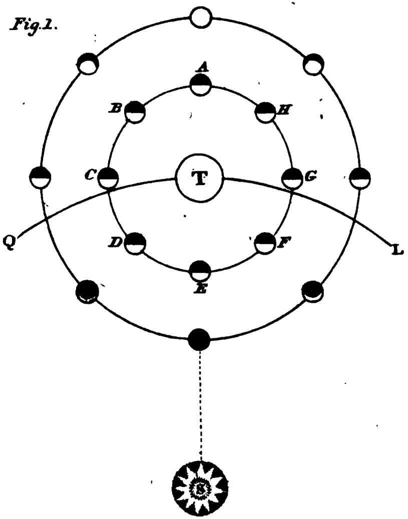
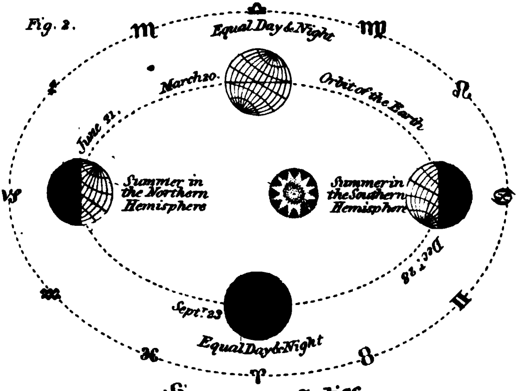


Fig. 2.



Signs of the Zodiac

N. & S. S. Jocelyn Sc.

But the orbit of the Moon, makes an angle with the ecliptic of 5⅓°. It will therefore appear in one half of its orbit, north of the apparent annual path of the Sun among the stars, and the other half of its orbit, south of the Ecliptic. When it crosses the Ecliptic, as it must do twice in every revolution, these are its *nodes*.

When a full Moon occurs at a greater distance than 12° from one of its nodes, no lunar eclipse can reach any part of the Earth. If within 12° of a node at the *full*, either a *partial* or *total* eclipse will take place. If *total*, it would be visible over a whole hemisphere, if *partial*, it might not be. In a *partial lunar* eclipse, but a part of the Moon's disc passes through the shadow of the Earth; in a *total* eclipse the *whole*. *Partial* eclipses may last but a short period; total lunar eclipses will continue from less than *three hours*, to nearly *four* hours. In a total eclipse, the Moon is visible and of a copper color.

The shadow of the Earth is of a conical shape, because the Sun is vastly larger than the planet; and the orbits of both the Earth and Moon, are ellipses, and not circles; therefore the width of the shadow of the Earth, where the Moon passes through it in eclipses, will vary very considerably. The longest eclipse of the *lesser light* will occur, when the Sun is most remote from the Earth, and the Moon is nearest; the shortest, when the Moon is remotest, and the Sun nearest. An eclipse of the Moon, always commences on its eastern limb or edge.

How near to a node must the Moon be, to occasion an eclipse? In total lunar eclipses, is the Moon visible? What is its color? How long may such eclipse continue?

What reasons are assigned for the variation in the duration of lunar eclipses? When will they be longest?—when shortest? On which limb of the Moon do they commence?

At Alexandria, in Egypt, more than 2000 years ago, the Moon was seen eclipsed when rising; while the Sun was still above the horizon. When the refractive properties of the atmosphere are discussed, the cause of this interesting phenomenon will be assigned. But tables of the Moon's present place, would not admit of that eclipse having commenced at Alexandria, until the Moon was nearly two hours above the horizon. But the phenomenon was so peculiar, how could the observer be mistaken? The true solution is this, that the Moon is nearer to the Earth now, than it then was; but La Place has demonstrated, that the orbit of the Earth is less elliptical now, than then, but that the variations in orbits and distances are all within known limits.

The average number of total lunar eclipses in a century, is about 30. The average number of eclipses of both luminaries in a year, is about four. There may be seven eclipses in a year, and there may be but two. If but two, they will both be of the Sun.

SOLAR ECLIPSES.

These are occasioned by the Moon's passing between the Earth and the Sun; and will be easily understood by consulting Plate iv. Figure 2.

Eclipses of the sun may be either *partial*, *annular*, or *total*. *Partial* eclipses of the Sun will occur

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What phenomenon occurred at Alexandria? How does that prove the Moon nearer to the Earth now, than then? What has La Place discovered? What is the average number of total lunar eclipses in a century? What the average number of eclipses in a year? What the extremes?

What occasions a solar eclipse? When will partial solar eclipses occur?

when the conjunction takes place, not in one of the Moon's nodes, but within 17° of one of them. A change of the moon exactly in one node of it will occasion an *annular*, or a *total* eclipse, over a small portion of the enlightened hemisphere; a larger portion will see a partial eclipse, and nearly one half that hemisphere, will not even have a partial one. On this account, while more solar than lunar eclipses occur in a century, fewer eclipses of the Sun will be seen in a given place, than of the Moon.

The *annular* or *ring* eclipse, derives its name from the luminous ring which surrounds the Moon, when a central solar eclipse occurs at the greatest distance of this satellite from the Earth.

The annular eclipses for the United States in the *nineteenth* century, are but three. One occurred in 1811; another is predicted for 1831, which will appear annular in quite the southern part of the Union; and one in 1838, which will be central in Virginia, but may be barely annular in some parts of New-England. There is a peculiar refraction of light, or radiation of the primary colors, in annular eclipses, which is supposed to be produced by the atmosphere of the Moon.

TOTAL SOLAR ECLIPSES.

It will be seen by a reference to Plate iv, Figure 2, that a *total* eclipse of the Sun, can never extend far north or south; not 200 miles in the most favorable circumstances; though the Earth's rotation on its axis, will cause it to extend farther east and west; and the total darkness can never last more than from 4 to 8 minutes.

When an *annular?* Why called *annular?*

What annular eclipses for the United States in the 19th century are named? What is supposed to occasion the colors in an *annular* eclipse?

How extensive the limits north and south of a *total* solar eclipse? How long can total darkness continue?

The only total eclipse, which the compiler of this Manual ever witnessed, or ever expects to behold, was that of 1806. It was a bright morning in the middle of June, when creation was rejoicing in renovated vigor, and decked in all the variegated beauties of Spring. Before the Sun had arrived at the meridian, the landscape began to assume a yellow, sombre, gloomy hue. Mercury stepped forth, and several of the fixed stars successively appeared.

The animal kingdom was seized with consternation. The beasts ceased their grazing. The tenants of the farm yard hastened to their perches. The songsters of the grove, with plaintive notes, repaired to their posts of nightly retirement. The chills and dews of an autumnal evening descended. A dense cloud of darkness was seen approaching with astonishing velocity. And when the last ray of light was intercepted, the heart involuntarily throbbed with anxiety. But before five long minutes had transpired, a ray descended, imparting *light* to the countenance, and *joy* to the heart. And when the eclipse had slowly and sullenly retired, creation resumed its beauty, and spontaneously burst forth in song.

UMBRA AND PENUMBRA, IN ECLIPSES.

The *umbra* and *penumbra*, in a solar eclipse, may be explained by a reference to Plate iv. Figure 4. Let S be the Sun, M the Moon, A B or C D, the surface of the Earth ; then *x* V *z* will be the Moon's *umbra*, in which, no part of the Sun can be seen. The space comprehended between the umbra and *x o k* and *z* P *g*, is called the *penumbra*, in which part of the Sun only is seen.

Now it is evident that if A B be the surface of the earth, the space between *m n*, where the umbra falls, will suffer a *total eclipse ;* the parts *o m* and *n* P, will have a *partial eclipse ;* but to all the other parts of the earth there will be *no eclipse.*

But as the earth is at different times at different distances from the Moon, suppose, again, C D to

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What account can you give of the *total* eclipse of 1806 ?

be the surface of the earth ; then as the umbra reaches but to V, the space within *c f* will suffer an *annular eclipse*, and the Sun will appear on every side of the Moon in the *form of a ring*. The parts *k c* and *f g* will have a *partial eclipse*, and to the other parts of the earth there will be *no eclipse*. Hence it is evident, that in this last case, supposing C D the earth, there can be no *total eclipse any where*, as the Moon's umbra does not reach the earth.

A short catalogue of some eclipses observed by the ancients, will be subjoined from Struyk's elaborate Tables. A Table, embracing the eclipses calculated for the capitol at Washington for half a century, commencing with 1831, will likewise be given. This will be extracted from an American work by John Vose, Esq., from which, the student in *practical* astronomy may derive very important aid.

ECLIPSES,

Selected from Struyk's Catalogue.

Year before Christ	Luminary.	Place where observed.	Digits Eclipsed.	Year before Christ	Luminary.	Place where observed.	Digits Eclipsed.
721	☽	Babylon	Total	60	⊙	Gibraltar	An'lr
431	⊙	Athens	11	54	⊙	Canton	Total
425	☽	Athens	Total	45	☽	Rome	Total
403	⊙	Pekin	10	28	⊙	Pekin	Total
340	⊙	Zante	9	26	⊙	Canton	11
198	⊙	Rome	unk'n	24	⊙	Pekin	2
63	☽	Rome	Total	2	⊙	Canton	11

What is the earliest eclipse inserted in the table from Struyk? Where observed?

ECLIPSES CONTINUED.

After Christ				After Christ			
1	⊙	Pekin	11	976	☽	London	Total
5	⊙	Rome	4	1026	⊙	London	11
37	⊙	Canton	Total	1113	⊙	Jerusalem	9
46	☽	Rome	Total	1230	⊙	Naples	Total
133	☽	Alexand'a	Total	1255	⊙	Cons'ple	An'lr
237	⊙	Bologna	Total	1415	⊙	Wet'mb.	Total
334	⊙	Toledo	An'lr	*1540	⊙	London	Total
360	⊙	Ispahan	An'lr	1603	⊙	Rome	11
540	⊙	London	8	1609	⊙	Canada	4
582	☽	Calais	Total	1684	⊙	London	Total
718	⊙	Cons'ple	Total	1696	☽	London	Total
810	⊙	Paris	Total	1699	⊙	London	9

Total eclipses for central Europe in the 18th century. Two *solar* eclipses, one in May, 1715, and the other in May, 1724, were calculated. Besides these there were 28 lunar eclipses. In the years 1703, 1736, 1768, and 1790, there were two in a year.

Eclipses calculated for the Capitol for half a century from 1831. To add to the general utility of the table, a few eclipses are inserted, not visible at Washington City. The time set to solar eclipses is the middle of each eclipse, as seen from the Capitol; to lunar, the minute of opposition. Both are reduced to apparent time.

What total solar eclipses occurred in central Europe the last century?

* Below this, they are from Ricciolus, and calculated.

Fig. 1. Eclipse of the Moon.

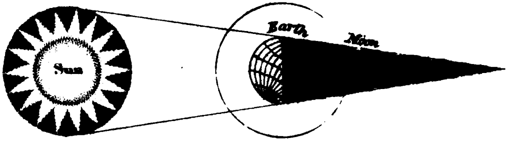


Fig. 2. Eclipse of the Sun.

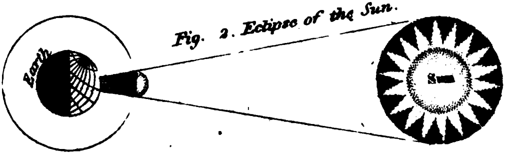


Fig. 3. Cylindrical Rays.

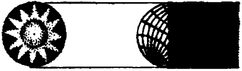


Fig 4 Conical Rays.

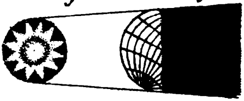


Fig. 5. Umbra & Penumbra.

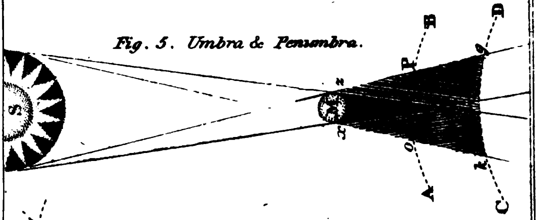
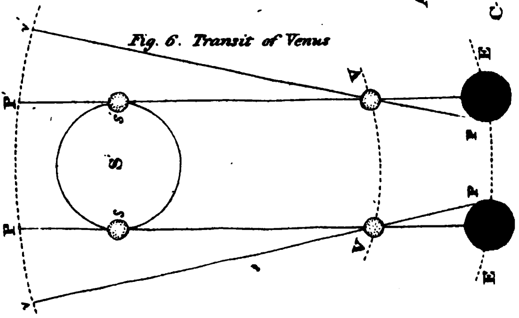


Fig. 6. Transit of Venus



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Year.	Lum	Month	D	H	M	A P M	NOTANDA.
1831	☉	Feb.	12	0	35	P M	Annular over a large S. section of the U.
	☽	Aug.	23	4	57	A M	
1832	☉	Feb.	1	5	10	P M	Visible in the W. part of the Union.
	☉	July	27	7	34	A M	
1833	☽	Jan.	6	2	48	A M	
	☽	July	1	7	32	P M	About total.
	☽	Dec.	26	4	30	P M	Total.
1834	☽	June	21	3	13	A M	Total.
	☉	Nov.	30	2	38	P M	Total. Charleston, S. C. *
	☽	Dec.	15	11	50	P M	Those with the asterisk are inserted from the American Almanack, 1830.
1835							
1836	☽	May	1	3	6	A M	
	☉	May	15	8	14	A M	
	☽	Oct.	24	8	22	A M	Visible in Mo. Ter.
1837	☽	Oct.	13	6	29	P M	Total.
1838	☽	April	9	9	0	P M	
	☉	Sept.	18	4	32	P M	Annular in Virginia.
1839							
1840	☽	Aug.	13	2	9	A M	
1841	☽	Feb.	5	8	49	P M	Total.
	☽	Aug.	2	4	49	A M	Total.
1842	☽	July	14	5	43	A M	Visible at Astoria.
1843	☽	Dec.	6	7	7	P M	Very small.
1844	☽	Nov.	24	6	51	P M	Total.
	☉	Dec.	9	4	19	P M	Small.
1845	☉	May	6			A M	Sun rises a little eclipsed.
	☽	Nov.	13	8	7	P M	
1846	☉	April	25	0	6	P M	
1847							
1848	☽	Sept.	13	1	23	A M	Total.
1849	☽	March	8	7	48	P M	
1850							
1851	☽	July	13	2	8	A M	
	☉	July	28	8	11	A M	
1852	☽	Jan.	7	1	3	A M	Total.
	☽	Dec.	26			A M	Begins 6h. 28m.

What day and hour in 1831 will there be an *annular* eclipse? Where? When will there be another total solar eclipse in the United States? Where?

Year.	Lum.	Month	D	H	M	A P M	NOTANDA.
1853	☽	Jan.	21	1	3	A M	Small.
1854	☽	Nov.	4	4	22	P M	Very small. Visible in N. E.
1855	☽	May	1	11	6	P M	Total.
	☽	Oct.	25	2	42	A M	Total.
1856	☽	April	20	4	10	A M	
	☽	Oct.	13	6	12	P M	
1857							
1858	☽	Feb.	27	4	55	P M	Moon rises partially eclipsed.
	⊙	March	15	6	16	A M	
1859	☽	Feb.	17	5	36	A M	Total.
	⊙	July	29	5	44	P M	Small.
1860	☽	Feb.	6	9	17	P M	
	⊙	July	18	7	55	A M	
1861	☽	Dec.	17	3	9	A M	
	⊙	Dec.	31	7	45	A M	
1862	☽	June	12	1	18	A M	Total.
	☽	Dec.	6	2	43	A M	Total.
1863	☽	June	1	6	30	P M	Total. Moon rises eclipsed.
	☽	Nov.	25	4	21	A M	
1864							
1865	☽	April	10	11	29	P M	Very small.
	☽	Oct.	4	5	50	P M	Very small.
	⊙	Oct.	19	10	27	A M	Annular at Wilmington, S. C.*
1866	☽	March	40	11	30	P M	Total.
1867	☽	March	20	3	45	A M	
	☽	Sept.	13	7	30	P M	
1868							
1869	☽	Jan.	27	8	21	P M	
	⊙	Aug.	7	6	5	P M	Total over a southern section of the Union.
1870							
1871	☽	Jan.	6	4	9	P M	Moon rises partially eclipsed.
1872	☽	Nov.	15	0	29	A M	Very small.
1873	☽	May	12	6	23	A M	Com. 4h. 34′. Total in the w. s.
1874	☽	Oct.	25	2	37	A M	N. total.
1875	⊙	Sept.	29	6	12	A M	Annular at Boston.*
1876	☽	March	10	1	5	A M	
	⊙	March	25	4	45	P M	Small.
1877	☽	Aug.	23	6	2	P M	Total. Moon rises eclipsed.
1878	☽	Feb.	17	5	58	A M	
	⊙	July	29	5	35	P M	
	☽	Aug.	12	7	3	P M	
1879							
1880	⊙	Dec.	31	7	42	A M	

The remainder of the eclipses for the 19th Century, as seen at the CAPITOL, may be given summarily, thus: In the Years 1885, 1886, 1889, 1892, 1897, 1900, there will be *solar* eclipses; in 1886 two. The *lunar* eclipses will be 18 in number, 6 of which will be *total*.

No *total* solar eclipse is calculated for the capital of France in the nineteenth century. The eclipse of 1836 which has been described, as so intensely interesting a scene in New-England, was but about 4 Digits eclipsed at Paris. The only *annular* eclipse there this century, will be in 1847.

CHAPTER XIII.

DAY AND NIGHT.

THE vicissitudes of light and darkness, heat and cold, are so familiar to us, that we think little of their recurrence. But WISDOM and BENEVOLENCE are eminently conspicuous, in the admirable simplicity of their causes. The Sun and the other celestial bodies, *appear* to rise in the east, and set in the west. This *apparent* motion in them, is caused by the *real* motion of the earth on its axis. A trifle more than one rotation constitutes a day, because of the Earth's motion round the Sun. Three hundred and sixty-six rotations are required to give 365 days. About the 20th of March and the 23d of

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Is any total solar eclipse computed for Paris this century? When will an annular one occur there?

What is the *apparent* daily motion of the heavenly bodies? What occasions it? How many rotations of the Earth in 365 days? Why?

September, were we under the equator we should at noon see the Sun vertical, or directly over head. Then the northern and southern hemispheres would be equally illuminated, and the days and nights would be equal in length quite over the Globe. For this reason these periods are called *equinoxes.*

If the Equator coincided with the Ecliptic, as seen in Plate v. Figure 1, there would be no variation in the length of days, and no change of seasons. But these make with each other, an angle of 23° 28′; consequently from the vernal equinox in March, till about the 20th of June, which is called the summer solstice, the Sun appears to advance to the north: still at the Equator the Sun will be twelve hours above, and 12 hours below the horizon. But north of the Equator, it will be more than 12 hours above the horizon; at the Arctic pole 6 months; at the Arctic circle from 12 to 24 hours. In Latitude from 40° to 43°, the longest days will be from 15 to 15½ hours. The Sun will appear to rise in the north east, and set in the north west. The twilight will be seen till 9, P. M. and by 3, A. M. In the 60th degree of Latitude, the Sun will be 18¾ hours above the horizon, and the twilight will not cease to be visible. At midnight its place will be due north.

When the days are longest, the nights of course will be shortest. The vicissitudes in the length of the days in the southern hemisphere will be similar, but in the other, six months.

When do the equinoxes occur? Why called equinoxes?

What occasions the inequality in the length of days? What is the greatest length in the days at the Equator?—between 40° and 43° of north Latitude?—at the 60°?—between the Arctic circle and the pole?

The Instructer can further illustrate this subject from Plate v. Figure 2, or from a terrestrial Globe rectified to the Latitude where he is.

At the rising and setting of the Sun, rays of light and rays of caloric fall more obliquely than at mid-day, consequently they have the greatest power at noon. But the earth has accumulated heat from the Sun's influence, which is radiated between 12 and 3 o'clock to such a degree as to render it warmest usually about 2 o'clock.

THE SEASONS.

The inclination of the axis of the Earth causes the Sun not to shine on one part of its surface, for months. This portion of the Earth is called a frigid zone. One half of each year, the Sun's rays are excluded from almost 23½°, round the north pole, and the other half of the year, from the same extent round the south pole; consequently there are *two* frigid zones.

That portion of the Earth, which receives the rays of the Sun in a vertical, or perpendicular direction, is called the *torrid* zone. This zone extends 23° 28′ each side of the Equator, making almost 47° in breadth.

The portions of the Earth, which are enlightened every day in the year, but where the Sun's rays are never vertical, are called *temperate* zones. The whole number of zones is *five*; one torrid, two temperate, and two frigid zones.

The circles which bound the torrid zone are called tropics, the one north of the Equator, is the tro-

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How can this subject be well illustrated? How do the rays of the Sun fall morning and evening? What effect results from this fact? What hour is the warmest?

What causes the disappearance of the Sun for months? On what parts of the Earth is this witnessed? What are they called? What makes the torrid zone? How broad is it? Where are the *temperate* zones? How many zones?

pic of Cancer, that south, is the tropic of Capricorn, because the Sun is in the signs Cancer and Capricorn, when over these circles.

The circle which bounds the north frigid zone, is called the Arctic circle; because the star Arcturus is in the northern hemisphere; and the opposite polar circle is called Antarctic, because opposite to the Arctic.

While the Earth is passing through the signs of Libra, Scorpio, and Sagittarius, the Sun appears to pass through Aries, Taurus, and Gemini, and then seems advancing north, from the Equator. These in Astronomy are the *spring* signs. From the 20th of March, at which time the sun is seen at the beginning of Aries, till the 20th of June, when its place is at the beginning of Cancer, its rays are becoming more and more direct in all places north of 23° 28′. Consequently the rays of the Sun have increasing power. While the Sun appears to pass through Cancer, Leo, and Virgo, it seems receding to the autumnal equinox, the 23d of September. The last three signs are called *summer* signs. The Earth has accumulated so much heat before the summer solstice at the 20th of June, that the radiation of that heat with the Sun's continued influence usually gives the warmest weather in July and August.

After the autumnal equinox, the Sun appears to be passing through Libra, Scorpio, and Sagittarius, called *autumnal* signs; and continues receding from the northern hemisphere: consequently its

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What are those circles called which are between the *torrid* and *temperate* zones?—between the temperate and frigid zones? What signs are called *spring* signs?—*summer* signs?—*autumnal signs*?

rays are becoming more oblique with us, and have diminished power. Till the 20th of December the heat of summer continues to be radiated from the Earth in such measure, that the coldest weather is most commonly the last of January. The signs Capricornus, Aquarius, and Pisces, in which the Sun appears between the winter solstice, the 20th of December, and the vernal equinox, the 20th of March, are called *winter* signs. Warmth from the Sun is in proportion to the density of the atmosphere, to the directness of the Sun's rays, and to the time of its continuance above the horizon.

Reference to Plate iii. Figure 2, will aid in this illustration.

Central parts of the torrid zone, have only two seasons; the *dry* or summer, during the intense heat of which, the soil often becomes parched; and the *wet* or winter, when incessant torrents of rain descend. Near the polar circles the transitions from winter to summer, and summer to winter, are so sudden, that they can scarcely be said to have intermediate seasons. It is only in the lower latitudes of the temperate zones, that months of *spring* paint the landscape and *perfume* the air; or the brown fulness of *protracted* autumn, allows the husbandman at his leisure to fill his store houses with plenty.

The summer is longest in the northern hemisphere, because the orbit of the Earth is elliptical; and the Sun is in one of the foci of that ellipse. Between the vernal and the autumnal equinox,

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What are *winter* signs? When is it common to have the warmest weather? Why? When the coldest? Why? On what does heat depend? How many seasons in the *torrid zone?*—in the frigid? Where are the four seasons most regular? In which hemisphere is the summer longest? Why?

there is included more than half the Earth's orbit; and in that half it revolves with less velocity, than in the other half; consequently, almost 8 days more time is consumed.

We are about 3 millions of miles nearer to the Sun in January, than in July. It has already been shown, what occasions the heat of summer; and Plate v. Figure 3, will further illustrate the subject, by giving definite views of what are direct, and what are oblique rays.

Calculations of some accuracy may here be useful:

	D.	H.	M
From the vernal equinox to the summer solstice, there are,	92	21	14
From the summer solstice to the autumnal equinox,	93	13	34
From the autumnal equinox to the winter solstice,	89	16	47
From the winter solstice to the vernal equinox,	89	1	42

"According to the chronology of the Hebrew Bible, the Earth was created 4004 years before the birth of our Saviour. Astronomy shows that the great axis, or longest diameter of the elliptic orbit, in which our planet revolves round the Sun, as placed in one of the foci, coincided at that epoch, with the line of the equinoxes."

Professor URE's *Geology, published in London*, 1829.

The periods would then have been of equal length between the *vernal* equinox and the *autumnal;* and the *autumnal* equinox and the *vernal.* Why is it not *probable*, that Adam, at the time of the *autumnal* equinox, first opened his eyes on the matured fruits of the northern hemisphere, in which he was located. Perhaps, on the *demiurgic week*, as it is sometimes called, the seasons might have commenced all over the globe, as they would be succeeding years at the *autumnal* equinox.

How much nearer are we to the Sun, in January than in July?

What accurate calculations are given, respecting the periods between the equinoxes and solstices?

Fig. 1.

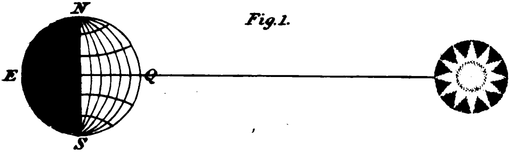


Fig. 2.

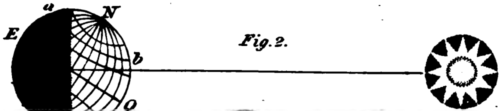


Fig. 3.

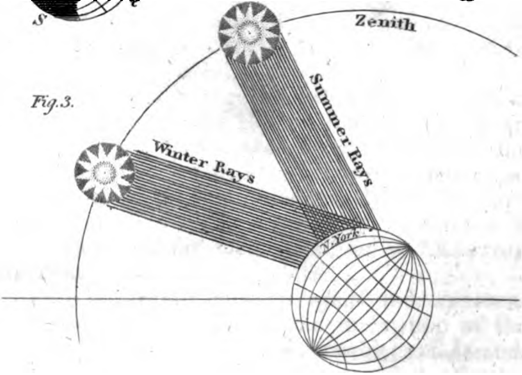


Fig. 4.

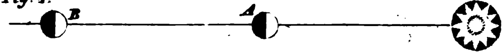


Fig. 5.

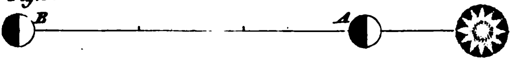
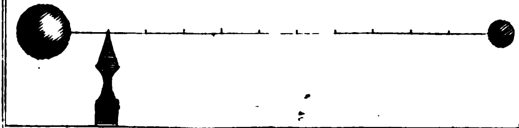


Fig. 6.



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CHAPTER XIV.

EQUATION OF TIME.

THE period required by the revolution of the Earth round the Sun to bring a given star in precisely the same direction, is 365*d.* 6*h.* 9′ 12″. This is called a *siderial* year. The period from one vernal equinox to another is 365*d.* 5*h.* 48′ 49″. This is called a *solar* year. The cause of this variation, will be assigned under the head of the *precession* of the *equinoxes.*

Were a clock so regulated, that from the 15th of June one year, to the 15th of June the next year, there should not be a second's variation with the Sun, that clock would keep *mean time*, but apparent time by the Sun would rarely be the same during the year. The cause of this difference is to be accounted for, under this head of EQUATION OF TIME.

This *difference* between *equal* and *apparent* time, depends, *first* upon the inclination of the Earth's axis to the plane of its orbit; and *secondly*, upon the elliptical, or oval form of the Earth's orbit; for being an ellipse, the Earth's motion is quicker in its *perihelion*, than in its *aphelion.*

The rotation of the Earth upon its axis, is the most equable motion in nature, and is completed in 23 hours, 56 minutes, and 4 seconds. This space is called a *siderial day*, because any meridian on the Earth will revolve from a fixed star to that star again in this time.

What is a *siderial* year? How long? What is a *solar* year? How long? On what causes depend the difference between *mean* and *apparent* time? How long is a *siderial* day?

Hence, if the Earth had *only a diurnal motion*, the day would be nearly four minutes *shorter* than it is.

But a solar, or natural day, which our clocks are intended to measure, is the time which any meridian on the Earth will take in revolving *from the Sun, to the Sun again*, which is about 24 hours, sometimes a little more, sometimes less. This is occasioned by the Earth's advancing nearly a degree in its orbit, in the same time that it turns eastward on its axis; and hence the Earth must make *more than a complete* rotation, before it can come into the same position with the Sun, that it had the day before.

Some idea of this may be formed by the hands of a clock; suppose both of them to set off together at twelve o'clock, the minute hand must travel *more than a whole circle* before it will overtake the hour hand; that is, before they will be in the same relative position.

If the Equator coincided with the Ecliptic, and the orbit of the Earth were a perfect circle, an equal period of 24 hours would transpire between the Sun's appearing in the meridian one day and the next throughout the year. But the angle of 23° 28′, made by the Ecliptic with the Equator is causing unequal portions of the Ecliptic to correspond with equal portions of the Equator. This must affect the apparent time from the Sun, and can easily be explained by the instructer on the Globe. Suppose, for example, that the Sun and a star were to set out together from one of the equinoctial points, and to move continually through equal arcs

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What is a *solar* day?
What illustration can be given from a clock?
How can this subject be illustrated on a globe?

in equal times; the star in the Equator and the Sun in the Ecliptic: then it is plain that the star moving in the Equator, would always return to the meridian exactly at the end of every 24 hours, as measured by a well regulated clock, that keeps equal time; but the Sun, moving in the Ecliptic would come to the meridian, sometimes sooner than the star and sometimes later, according to their relative situations; and they would never be found upon that circle exactly together except on four days of the year; namely, on the 20th of March, when the Sun enters Aries; on the 21st of June, when he enters Cancer; on the 23d of September, when he enters Libra; and on the 21st of December, when he enters Capricorn.

Again it must be observed, that if the Earth's motion in its orbit were uniform, as it would be if the orbit were circular, then the whole difference between *equal time* by the clock, and *apparent time* by the Sun, would arise from the inclination of the Earth's axis. But this is not the case, for the Earth travels when *nearest* the Sun, that is, in the winter, *more than a degree* in 24 hours;—and when remotest from the Sun, that is, in summer, *less* than a degree in the same time.

From this cause the natural day would be of the greatest length, when the Earth was nearest the Sun, for it must continue turning the longest time after an entire rotation, in order to bring the meridian of any place to the Sun again; and the shortest day, when the Earth moves slowest in her orbit.

What effect on this difference in *mean* and *apparent* time has the unequal velocities of the Earth in different parts of its orbit?

The above irregularities, combined with those arising from the inclination of the Earth's axis make up that difference which is shown by the equation table, which is here subjoined.

This table is adapted to the second year after Leap year, but will be found within a minute of the truth for every year, and therefore is sufficiently accurate for the regulation of common clocks and watches.

EQUATION TABLE.

Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.		Months.	Days.	Equ. in Minutes.	
Jan.	1	4	Clock faster than the Sun.	April	1	4	Cl'k faster.	August	9	5	Clock faster.	Oct.	27	16	Clock slower than the Sun.
	3	5			4	3			15	4		Nov.	15	15	
	5	6			7	2			20	3			20	14	
	7	7			11	1			24	2			24	13	
	9	8			15	0			28	1			27	12	
	12	9			*				30	0			30	11	
	15	10			19	1	Clock slower.		*			Dec.	2	10	
	18	11			24	2		Sept.	3	1	Clock slower than the Sun.		5	9	
	21	12			30	3			6	2			7	8	
	25	13		May	13	4			9	3			9	7	
	31	14			29	3			12	4			11	6	
Feb.	10	15		June	5	2			15	5			13	5	
	21	14			10	1			18	6			16	4	
	27	13			15	0			21	7			18	3	
March	4	12			*				24	8			20	2	
	8	11			20	1	Clock faster.		27	9			22	1	
	12	10			25	2			30	10			24	0	
	15	9			29	3		Oct.	3	11			*		
	19	8		July	5	4			6	12			26	1	Faster.
	22	7			11	5			10	13			28	2	
	25	6			28	6			14	14			30	3	
	28	5							19	15					

From the equation table, how many times in the year will the Sun and clock be together? How widely apart?

CHAPTER XV.

HARVEST MOON, AND POLAR APPEARANCES.

FERGUSON has given so lucid an explanation of the Harvest Moon, on the common terrestrial globe, that I choose to use his language entirely.

"It is generally believed that the Moon rises about 50 minutes later every day than on the preceding; but this is true only with regard to places on the Equator. In places of considerable Latitude, there is a remarkable difference, especially in the harvest time, with which farmers were better acquainted than astronomers till of late; and gratefully ascribed the early rising of the full Moon at that time of the year to the goodness of God, not doubting that He had ordered it so on purpose, to give them an immediate supply of moonlight after sunset, for their greater convenience in reaping the fruits of the Earth."

"In this instance of the harvest Moon, as in many other discoverable by Astronomy, the wisdom and beneficence of the Deity is conspicuous, who really ordered the course of the Moon, so as to bestow more or less light on all parts of the Earth, as their several circumstances and seasons render it more or less serviceable. About the Equator, where there is no variety of seasons, and the weather changes seldom, and at stated times, moonlight is not necessary for gathering in the produce of the ground; and there the Moon rises about 50 minutes later every day or night, than on

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Who first observed the harvest Moon? To what was it attributed? Is it not justly ascribed to *benevolcnt* design? How does the full Moon rise at the Equator?

the former. At considerable distances from the Equator, where the weather and seasons are more uncertain, the autumnal full Moon rises very soon after sunset, for several evenings together. At the polar circles, where the mild season is of very short duration, the autumnal full Moon rises at sunset from the first to the third quarter. And at the poles, where the Sun is for half a year absent, the winter full Moons shine constantly without setting, from the first to the third quarter.

It is soon said that all these phenomena are owing to the different angles made by the horizon and different parts of the Moon's orbit; and that the Moon can be full but once or twice in a year, in these parts of her orbit which rise with the least angles. But to explain this subject intelligibly, we must dwell longer upon it.

The plane of the Equator is perpendicular to the Earth's axis: and therefore, as the Earth turns on its axis, all parts of the Equator make equal angles with the horizon both at rising and setting; so that equal portions of it always rise or set in equal times. Consequently, if the Moon's motion were equable, and in the Equator at the rate of 12° 11′, it would rise and set about 50 minutes later every day than on the preceding; for 12° 11′ of the Equator, rise or set in 50 minutes of time in all latitudes.

But the Moon's motion is so nearly in the Ecliptic that we may consider her at present as moving in it. Now the different parts of the Ecliptic, on account of its obliquity to the Earth's axis, make very different angles with the horizon as they rise or set. Those parts or signs which rise with the smallest angles set with the greatest and *vice versa.*

How does the full Moon rise in the temperate zones?—at the poles?

In equal times, whenever this angle is least, a greater portion of the Ecliptic rises than when the angle is larger; as may be seen by elevating the pole of a globe to any considerable latitude, and then turning it round its axis in the horizon. Consequently, when the Moon is in those signs which rise or set with the smallest angles, it rises or sets with the least difference of time; and with the greatest difference, in those signs, which rise or set with the greatest angles.

In northern Latitudes, the smallest angle made by the Ecliptic and horizon, is when Aries rises, at which time Libra sets; the greatest, when Libra rises, at which time Aries sets. From the rising of Aries to the rising of Libra, (which is twelve siderial hours,) the angle increases; and from the rising of Libra to the rising of Aries, it decreases in the same proportion. By this article and the preceding, it appears that the Ecliptic rises fastest about Aries, and slowest about Libra.

All these things will be made plain by rectifying a globe to the Latitude of a given place, and then putting small patches on the Ecliptic of that globe, as far from one another, as the moon moves from any point of the celestial Ecliptic in 24 hours, which at a mean rate is 13½ degrees; and then, in turning the globe round, observe the rising and setting of the patches in the horizon, as the index points out the different times in the hour circle."

Those years, in which the *harvest Moon* will be most beneficial in the northern hemisphere for half a century, will be from 1835 to 1843, and from 1853 to 1861.

How can this subject be illustrated on a globe?

POLAR APPEARANCES.

Could the enterprising adventurers now attempting it, reach the Arctic pole, they would see the Sun at the vernal equinox, begin to be barely visible above the horizon; and in 24 hours it would appear to pass quite through the whole points of the compass. The next 24 hours would present a similar appearance, but with the Sun a trifle more elevated above the horizon. This elevation would continue to increase till the 20th of June, the *summer* solstice. From that period the Sun would be more and more depressed till the 23d of September, when it would sink below the horizon. But the twilight would then remain at that point of the compass where the Sun was, as it appears to us a few minutes before, or after sunrise. As the Sun became vertical farther and farther south, this twilight would become more and more faint, till four fifths of its declination south of the Equator was reached; when its light would no longer be visible. While the declination of the Sun *increased* the other 5½°, and till its declination had *decreased* 5½°, twilight would not be seen. From that time it would be visible and increase till the vernal equinox, and then the Sun would appear above the horizon again. This estimate is without allowing for the refractive powers of the atmosphere; a subject to be resumed in the next chapter.

If the Moon revolved round the Earth exactly in the Ecliptic, it would, at the full, be as much above the horizon, at the north pole, as the Sun was south of the Equator. Of course, at the win-

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What must be the annual appearances of the Sun at the north pole? What of the Moon?

ter solstice, when no twilight was enjoyed at the Arctic pole, the Moon would appear above the horizon at its first quarter, and remain passing round and becoming more elevated till the full, then it would descend and diminish gradually till the last quarter, when it would disappear for two weeks. The Moon's variation from the Ecliptic does not essentially alter the appearances.

Besides this amount of twilight and moonlight, there are frequent and very brilliant coruscations of the Aurora Borealis, supposed to be occasioned by the discharge of the electric fluid. Light at the north pole, adequate to all the purposes for which light is needed, is evidently enjoyed, and with much less inequality, when compared with equatorial regions, than is generally understood.

The same remarks apply to the south pole in the opposite period of the year; and the intermediate nine years, out of the almost 19 years, which are required for a complete revolution of the Moon's nodes.

He must be a dull scholar indeed, who does not in these circumstances of the harvest moon, and its polar appearances, discern legible inscriptions of the Creator's benevolent designs.

CHAPTER XVI.

ATMOSPHERE.

DIVINE Goodness has surrounded the Earth with a fluid mass of matter, which like other matter gravitates, or tends towards the centre of the Earth, moves with the Earth in its daily and yearly revolutions, and is exceedingly elastic. This fluid is

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What other illumination there ?
What is the atmosphere ?

called air, and constitutes the atmosphere. Water is 900, or 1000 times more dense than air at the surface of the Earth, and the higher we rise, the more rare it becomes, till it is too subtle to produce any sensible effect. The atmosphere is commonly estimated to extend 45 miles above the surface of the Earth. Its extreme rarity at that height, renders it difficult to ascertain how much higher it may rise. Experiments made with the barometer and air pump, prove that the usual weight of the atmosphere of one inch square, is 15 pounds; and the weight of the whole atmosphere, is equal to that of a leaden globe 60 miles in diameter. According to this computation, a middle sized person sustains a pressure from the atmosphere, amounting to 12 or 15 tons. This is so equally distributed on the surface of the body, and finds such resistance from the air contained in the pores of all animal bodies, as to render us insensible to its pressure. But when ascending three or four miles above the level of the ocean, either on a mountain or in a balloon, the removal of this pressure occasions peculiar sensations; as though all the fluids of the body were about to burst from their confinement.

The Andes have been climbed to an elevation where respiration was extremely difficult, and very painful sensations were produced. One aeronaut ascended so high, as to occasion swellings, which required medical aid for their removal; although his elevation was but a small part of 45 miles.

The atmosphere varies in density. With a westerly wind and clear cool weather, we have the air most dense; though we

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What is its density at the surface of the Earth? What is its elevation? What is the weight of a column one inch square? —of the whole atmosphere? Why are not animal bodies crushed by it?

What effects result from ascending very high? When is the atmosphere *most* dense?

often call warm damp air heavy, from the effects produced on our spirits.

The whole mass of the atmosphere contains an heterogeneous collection of particles, exhaled both from solid and fluid bodies on the surface of the Earth.

It serves not only to suspend the clouds, furnish us with wind and rain, and answer the common purposes of breathing, but is also the cause of the morning and evening twilight, and of all the glory and brightness of the firmament.

Experiments with the air pump prove, that without the air or atmosphere, no animal could exist; without its aid all vegetation would cease. Sound could not be produced without it, nor would there be rains or dews to moisten the ground.

Without an atmosphere, instead of a gradual increase and diminution of light morning and evening, none would appear before the Sun was above, and none after the Sun was below the horizon. Now the twilight begins and ends, when the Sun is 18° below the horizon at the Equator; 1 hour and $\frac{1}{5}$ earlier, than the Sun rose, and 1 hour $\frac{1}{5}$ later than it set.

The Sun at the solstices makes a longer twilight, and the higher the Latitude, the longer the twilight.

When treating of the Sun, it was stated, that colors exist exclusively in rays of light; and to prove this, we have only to separate the rays of light with a prism. It will exhibit to us all the colors of the rainbow; violet, indigo, blue, green, yellow, orange and red; seven primary colors. Those properties of bodies by which they absorb some of the rays of light and reflect others,

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From what is it exhaled? What purposes does it serve?

What gives brightness to the sky, and twilight? How many degrees below the horizon, is the Sun at the commencement or termination of the twilight? When is the twilight longest?

In what do colors exist? How many primary colors? What are they?

give the impression of color. The colors which are absorbed are invisible, the others we see.

When rays of light pass obliquely from a rarer to a denser medium, or the opposite, they are said to be refracted.

Let a stick be set obliquely in the water, rays coming from it beneath the water, will be bent when entering the rarer medium, the air; and will cause the stick to make an *apparent angle* at the surface of the water. Incline it in the opposite direction, and is seems bent the other way. This is what is called REFRACTION. The atmosphere, being more dense at the surface of the Earth than 45 miles above it; a ray of light, beginning to be refracted at that elevation, is bent more and more, till it reaches the eye of the observer. Of course it descends in a curve line.

These properties of the atmosphere prevent our seeing celestial bodies in their *true* places, except when in the zenith.

Let A, B, C, (Plate vi. Figure 1,) represent the surrounding atmosphere, *a* the *true* place of a star, *b* the *apparent* place. Let a ray fall from *a* on the surface of the atmosphere at A, and it will be refracted in the direction of the curve A D, because the density of the atmosphere increases, as it approaches the Earth's surface. Hence an observer at D will see the object at *b*.

It is in consequence of the refraction of the atmosphere, that *all heavenly bodies are seen for a short time before they rise* in the horizon, and also *after they have sunk below it.*

When is light said to be refracted? How illustrate refraction? In what line does a ray of light descend through the atmosphere? What effect has refraction on the position of the heavenly bodies?

How illustrate this? For what will this account?

REFRACTION

Fig. 1.

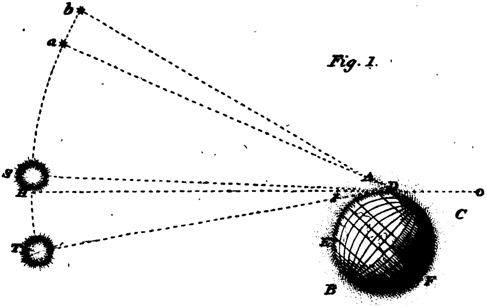
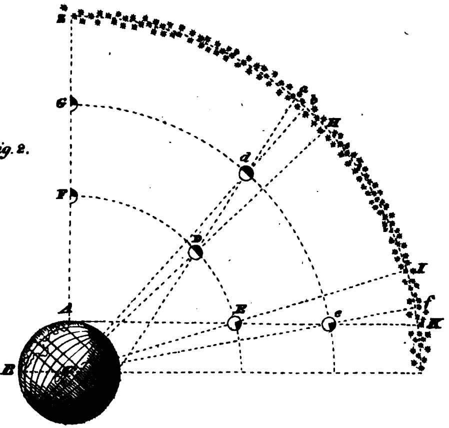


Fig. 2.



PARALLAX

N. & S. S. Jocelyn Sc.

At some periods of the year, the Sun appears five minutes sooner in the morning, and may be seen five minutes later at evening, than if no refraction existed; and about 3¼ minutes every day at a mean rate. Hence, when the Sun is at T *below* the horizon, a ray of light T I, proceeding from him, comes straight to I, where, falling on the atmosphere it is turned out of its direct, or rectilineal course, and is so bent down to the eye of the observer at D, that the Sun appears in the direction of the refracted ray above the horizon at S, as seen in Plate vi. Figure 1.

At the Equator, there will be, equal to two days more sunshine in a year, than without refraction; and the higher the Latitude, the greater the benefit from this property of the atmosphere.

MEAN ATMOSPHERICAL REFRACTIONS IN ALTITUDE.

App alt.	Re-frac.	App alt.	Re-frac.	App alt.	Re-frac.	App alt.	Re-frac.	App alt.	Re-frac.
°	′ ′	°	′ ″	°	′ ″	°	′ ″	°	′ ″
0	33 0	14	3 45	28	1 47	42	1 3	68	23
1	24 29	15	3 30	29	1 42	43	1 1	70	21
2	18 35	16	3 17	30	1 38	44	59	72	18
3	14 36	17	3 4	31	1 35	45	57	75	15
4	11 51	18	2 54	32	1 31	46	55	78	12
5	9 54	19	2 45	33	1 28	47	53	80	10
6	8 28	20	2 35	34	1 24	48	51	82	8
7	7 20	21	2 27	35	1 21	50	48	85	5
8	6 29	22	2 20	36	1 18	52	44	88	2
9	5 48	23	2 14	37	1 16	55	40	89	1
10	5 15	24	2 7	38	1 13	58	35	90	0
11	4 47	25	2 2	39	1 10	60	33		
12	4 23	26	1 56	40	1 8	62	30		
13	4 3	27	1 51	41	1 5	65	26		

How long may the Sun be seen before it rises?
What amount of Sun light in a year by refraction?

Some Hollanders, who wintered in Greenland about a century ago, had the Sun become visible in the south at noon, 17 days earlier than it would have done without refraction. It doubtless continued 17 days later, making the difference of 34 days in the year.

When the Sun is at the equinoxes, it shines some distance over both poles by refraction, and the twilight may scarcely cease to be visible even at the solstices.

ABERRATION OF LIGHT.

Light is more than 8 minutes in coming 95 millions of miles, in which time the Earth has moved more than 8 thousand miles in its orbit. Consequently a ray of light which left the Sun in the direction of the centre of the Earth, when it reaches the orbit of this planet, falls more than 8 thousand miles behind its centre. A ray that left the Sun in the direction of 8 thousand miles forward of the Earth's centre, is that by which we see the Sun when in the meridian. This is the *aberration of light.* From this cause we never see any of the heavenly bodies in their *true* places. The Moon being nearest, is least affected by it.

CHAPTER XVII.

PARALLAX.

THE subject of *parallax*, if attended with some difficulties to minds not conversant with the higher branches of Mathematics, is still of such vast importance in Astronomy, as to merit the most profound attention.

What was witnessed in Greenland?

What effect has refraction probably at the poles? What is aberration of light? What results from that?

A few definitions will here be given.

Two lines meeting thus < form an *angle*.

If one leg of dividers were set where those lines meet, and the other should describe an entire circle, that part of the circle included between those lines would be an *arc*. Let A *b*, in Plate vi. Fig. 1, represent an *angle*, whose *arc* between *a*, *b*, shall be called 10°, or $\frac{1}{36}$ part of a circle. Measure the distance between *a* and *b*, and see what proportion it bears to the *radius a* A, or *b* A. We will call that proportion as 1 to 6; that is, the distance from *a* to A where the lines meet, is six times as great as the distance from *a* to *b*. We have now learned a *proportion*, which will be found the same, whether the circle be *large* or *small*. Call that *arc* 1 inch and the *radius* 6 inches. Now if a circle were drawn so large that an *arc* of 10° measured 1 foot, the *radius* would be 6 feet; if the *arc* measured one mile, the *radius* would be six miles; if the *arc* measured one thousand miles, the *radius* would be six thousand miles.

Let us now apply this subject to celestial observations; first, in showing the *effect* of parallax, and secondly, its UTILITY.

The parallax of heavenly bodies is the difference between their *apparent altitude*, as seen from the *surface* of the Earth, and their *real altitude*, as seen from its *centre*.

Let C (Plate vi. Fig. 2,) represent the centre of the Earth; F D E, part of the Moon's orbit; G *d e*, part of the planet's orbit; Z K, part of the starry

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What is an *angle?* What is an *arc?* What a *radius?* About what is the proportion between an *arc* of 10° and the radius? How would you illustrate this proportion? What is parallax? How illustrate this?

heavens: now to a spectator at A, upon the surface of the Earth, let the Moon appear at E, in the horizon of A, and it will be referred to K; but if viewed from the centre at C, it will be referred to I: the difference between these places, or the arc I K, is called the *parallax in altitude;* and the angle A E C, is called the *parallactic angle.*

The parallax will be *greater* or *less*, as the objects are more or less distant from the Earth; thus the parallax I K, of E, is greater than the parallax *f* K, of *e*.

Besides, with the same object, when it is *in the horizon*, the parallax is the greatest, and *diminishes* as the body rises *to the zenith*, where the parallax is nothing. Thus, the horizontal parallax of E and *e* is greater than that of D and *d;* but the objects F and G, as seen from either A or C, appear in the *same place* Z, or in the zenith.

The difference in the Moon's place, as seen in the horizon, or the zenith, may be called its *horizontal parallax.* The whole difference between its *apparent* place, when *rising* and when *setting*, is twice its horizontal parallax. This being caused by the diurnal motion of the earth, often occasions the Moon's parallax to be called *diurnal.*

The *horizontal* parallax of the Moon is about 1° 1′—of the nearest planets much less; and of the Sun but about 8½″, proving it about 400 times as distant as the Moon. The diurnal motion of the Earth gives no perceptible parallax to any of the fixed stars. And all attempts have hitherto been unsuccessful, when made to find an *apparent*

Where will parallax be greatest? What is the Moon's parallax? What the Sun's? What effect has parallax on the heavenly bodies?

change in the position of the fixed stars, as observed the 23d of September or the 20th of March, having the whole diameter of the Earth's orbit, as an angle; called *annual parallax.*

As the parallax of celestial bodies *depresses* them, or causes them to appear *lower* than they really are, the difference must be added to their *apparent* altitude, to obtain their *true* altitude.

Thus far the *effect* of parallax has been described. Let the attention next be turned to its UTILITY. To minds unacquainted with mathematical science, and with the surprising resources of the human intellect, it often seems impracticable to measure distances and magnitudes, when removed many thousands, or even millions of miles from them. But parallax enables man to surmount difficulties of distance, and gauge the heavens.

DISTANCE OF THE MOON.

The distance of the Moon is easily ascertained. The *quadrant,* an instrument by which degrees and minutes among the heavenly bodies can be accurately measured, shows that the Moon's *apparent* place, as seen from the surface of the Earth, varies from its *true* place, if seen from the centre of the Earth, one degree. Now draw a circle, and divide it into 360 equal parts, called degrees. Let one of these degrees be called the arc; draw a line from each side of that arc, in the centre of the circle. Observe what proportion exists between the length of the *arc* of 1° and the *radius* of that circle. Suppose the *radius* is 60 times as long as the *arc.* You now have a proportion gained for use. The semi-diameter of the Earth which makes this arc of 1°, you may call in round numbers 4000

What instrument is used for finding degrees and minutes in the heavens? How may the Moon's distance be known by its parallax? What other illustration can be given?

miles; which multiplied by the *radius* 60, makes 240 thousand miles, the distance of the Moon from the Earth.

Again, Let us suppose the observer to be under the equator, with the Moon perfectly vertical. He then sees it in its *true* place among the stars. But when it rose that evening, it would *appear* 1° east of its *true* place, and when it set it would appear 1° west of its *true* place; a difference of 2° from its place of rising and its place of setting. This would be occasioned by the *diurnal* revolution of the Earth, making the observer's place vary the whole diameter of the Earth's orbit, which we call in round numbers 8000 miles. Draw the circle, and take an *arc* of 2 degrees. Find the proportion between the *arc* of 2°, and the *radius*, which we will call as 1 to 30. Now multiply 8000 miles, which subtends an *arc* of 2° at the distance of the Moon, by 30, and you have as before 240 thousand miles.

With the *quadrant*, or with the *micrometer* in a telescope, observe how broad the disc of the Moon seems, and it is found to be 31½′. This is its *apparent* diameter. If 1° at the Moon's distance is 4000 miles, then 31½ minutes, or something more than ½° will be a trifle more than 2000, or 2180 miles, which is the *real* diameter of the Moon.

Thus the *distance* of the Moon from the Earth, and its *magnitude*, are satisfactorily ascertained.

In one part of its orbit, the Moon is nearer to the Earth, than its opposite. When nearest, it is said to be in *Perigee;* when remotest, in *Apogee*. The medium between these, is called its *mean distance*.

How can the Moon's diameter be known?

When is the Moon in *perigee?* When in *apogee?*

The *diurnal parallax* of the Sun is so small, that it becomes more difficult to determine with *perfect accuracy* what it is; and an error of a few seconds in the observation, would occasion an error of millions of miles in the estimated distance. But Dr. Halley has the honour of having discovered and described, an effectual method of obtaining the *true* parallax of the Sun. This is by observations of a *transit* of *Venus* taken in different parts of the world, and compared together. He gave the necessary directions for such observations, 90 years previous to the transit of 1761. A compliance with his rules by astronomers in 1761, and in 1769, has demonstrated, that the Sun's true parallax is about 8½″, and its mean distance 95 millions of miles.

TRANSIT OF VENUS.

The following illustration of the *transit* of *Venus* is from GUY; and though *more lines* and *more explanation* would be needful to render it *perfectly correct* as a mathematical demonstration, it may aid the learner in appreciating the importance and utility of such transit.

Let S (Plate iv. Figure 6,) represent the Sun, and V V′ Venus at the beginning and end of her transit, as she would appear from the Earth's *centre;* also E E′ be the corresponding positions of the Earth at those times.

Then, if the observer were situated at C, the centre of the Earth, when Venus entered on the

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What difficulty attends determining the distance of the Sun? Who discovered an accurate method of finding the Sun's true parallax? What were the results of observations on the *transits* of Venus in 1761 and 1769? How can this be illustrated by a plate?

solar disc, she would appear as a small black spot at *s*, and the true place of both her and the eastern limb of the Sun would be *s*. But if the observer were situated at any point on the Earth's surface, as P, the apparent place of Venus would be at *v*, and the apparent place of the corresponding limb of the Sun would appear at P; and consequently Venus would appear to the eastward of the Sun, by a space equal to the arc *v* P, which is the difference of the parallaxes of these two bodies.

Hence the immersion of Venus would not take place so soon to an observer at P, as to one at C, by the time she would require to describe the apparent arc *v* P.

Now, as the transit always takes place during the *inferior* conjunction of the planet, the motions of both Venus and the Earth will then be from east to west, while the motion of the Earth on its axis is in a contrary direction. Consequently, while Venus and the Earth move in their orbits from V to V′, and from E to E′, the point P, which at the commencement of the motion was *west* of the centre, will at the end of it be on the *east* of it, as at P′. Hence the observer, who was supposed to be situated at C, would perceive Venus just leaving the Sun's disc, and her apparent place would be *s*′; while to the observer at P, her apparent place would be at v′ and that of the Sun's western limb at P. The apparent distance of Venus from the Sun at the end of the transit is therefore the arc *v*′ P, which is equal to the difference of the parallaxes of the Sun and Venus, as before.

Consequently, the time *of the duration*, as observed at the point P, will be *less* than the absolute duration by the time which the planet would require to describe the two apparent arcs v P and v' P or *twice the difference* of the parallaxes of the Sun and the planet.

PARALLAX OF THE SUN.

Here it will be assumed, that the transit of Venus, has given the Sun's horizontal parallax, as $8\frac{1}{2}''$. Draw a circle sufficiently large to have the 360° divided in 60 parts each, called minutes, and the minutes divided into 60 parts each, called seconds. Take $8\frac{1}{2}$ of these seconds and draw lines from each side of them to the centre of the circle. Ascertain the proportion between the *arc* of $8\frac{1}{2}''$ and the *radius*, or one of those lines. Suppose it to be as 1 to 24 thousand. That 1 in the *arc* is the semi-diameter of the Earth, which in miles is 3964. This number, multiplied by 24 thousand, will give 95 millions of miles, the *true mean* distance of the Earth from the Sun.

Now if the angle of 3964 miles, the distance from the centre to the surface of the Earth, seems at the Sun, but $8\frac{1}{2}''$, therefore for every $8\frac{1}{2}''$ in the *apparent* diameter of the Sun's disc we must compute 3964 miles.

Its mean apparent diameter is 32′ 1″, which reduced to seconds is 1921″. Multiply 1921″ by 3964 and divide the product by $8\frac{1}{2}''$, and you have the Sun's *real diameter*, which in round numbers, is 890 thousand miles.

The vast *importance* of correct observations of a transit of Venus, is thus clearly seen, as it enables man to throw his measuring line through millions of miles in space, and gauge the mighty dimensions of the "Sun shining in his strength." Yet this is but one item in many, of its high UTILITY.

When the true parallax of the Sun is found, how determine its distance—its magnitude?

About the commencement of the 17th century, **KEPLER** of Wirtemberg, in Germany, by his *observations* and *discoveries* laid the *corner stone* ot modern Astronomy. He discovered the *exact proportions* in the distances of the planets from the Sun, before the precise distance of any was known.

PROPORTIONAL DISTANCES.

Kepler discovered, by calculations founded on a series of the most accurate observations, *that the squares of the periods, in which any two planets complete their revolutions in their orbits, are proportional to the cubes of their mean distances from the Sun.*

This proportion requires illustration. Let the period of the Earth's revolution, be called 12 months, and the period of Mercury's revolution, 3 months. By the Sun's parallax learned from a transit of Venus, the Earth's distance is 95 millions of miles. By Kepler's law, the distance of Mercury from the Sun is to be sought.

The *square* of any number, is that number multiplied by itself. The square of two is four.

The *cube* of any number is that number multiplied twice by itself. The cube of 3 is 27; for 3 times 3 are 9; and 3 times are 27. The period of the Earth's revolution 12 months, which multiplied by 12, makes its square 144. The cube of the Earth distance, 95 millions multiplied by 95 millions and that product by 95 millions.

This round sum is again to be multiplied by 9, the *square* ot 3, the period in months, in which Mercury revolves round the Sun. Next, the whole product is to be divided by 144, and the *cube root* extracted, which will leave 37 millions of miles as the mean distance of Mercury.

What discovery did Kepler make respecting the proportional distances of the planets?

How may this be illustrated? What is a square? What is a cube? How determine the distance of Mercury from the Sun by knowing the period of the Earth's revolution, its mean distance from the Sun, and the period of Mercury's revolution? How determine the distance of Jupiter?

Both the *student* and the *reader*, are requested to fill out an additional illustration of Jupiter's mean distance.

It will be obvious, that if the true distances from the Sun, of the Earth and of each of the other planets can be ascertained, the nearest approach of each other planet to the Earth, and the remotest distance of each from the Earth can be known.

If Venus is 68 millions of miles from the Sun, and the Earth 95 millions, subtract the 68 from the 95, and you have 27 millions of miles, the distance of Venus in its *inferior* conjunction. To the distance of the Earth from the Sun, add the distance of Venus from it, and you have 163 millions of miles, the distance of Venus in its *superior* conjunction.

When the *true* distance, of each planet from the Earth, is thus ascertained, and their apparent diameters exactly measured, their real magnitudes can be known.

RELATIVE MAGNITUDES.

With a knowledge of their *real* magnitudes, the proportions in their magnitudes can be estimated; for all *spheres, or globes, are in proportion to one another as the cubes of their diameters.*

For illustration, let the diameter of the Earth be called in round numbers 8 thousand miles; and the diameter of Jupiter 90 thousand miles; in both cases a trifle exceeding their *real* diameters. The cube of Jupiter's diameter is 90 thousands, multiplied by 90 thousands, and that product by 90 thousands, making 729 millions. The cube of the Earth's diameter is 8 thousand miles multiplied by 8 thousands, and that product by 8 thousands; amounting to 512 thousands, by which divide 729 millions, the *cube* of Jupiter's diameter, and the result will be 14 hundred; proving that Jupiter has about 14 hundred times the bulk of the Earth.

If the distance of each planet from the Sun is known, how determine their distance from the Earth and their magnitudes? How would you illustrate this?

How can the comparative magnitudes of spheres be known? How would you illustrate this?

"To determine the area of surface in a sphere, multiply the circumference by the diameter.

"To determine the cubical contents of a sphere, multiply the area of surface by $\frac{1}{6}$th of the diameter." **Watts.**

Thus we learn, of what incalculable importance to science, are correct observations of a *transit of Venus*. No wonder, that all *ranks* and conditions of our race, feel interested in that event.

The governments of Europe, fitted out expeditions to different parts of the Globe in 1761 and 1769, and men of science encountered perils by sea and by land, for the express purpose of observing these transits. And millions of eyes, were intensely gazing on a dark spot crossing the disc of the Sun.

The methods of estimating the densities of the Earth and the heavenly bodies, belong to *Physical Astronomy*, to which the attention is next to be turned.

CHAPTER XVIII.

PHYSICAL ASTRONOMY.—GRAVITATION.

The mind may now advance, to that sublime department of science called Physical Astronomy; which developes *the laws of motion*, or the uniformity in which their resistible energies of their, Author, govern the mighty movements of material worlds.

That property in bodies, which is manifested in a tendency to approach each other, is called ATTRACTION.

The magnet attracts the needle. This is called the *attraction of magnetism*. The feather, suspended near an electrical con-

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How can the area of surface in a sphere be estimated? How can its cubical contents be determined?

What evidence has been given of the deep interest taken in the transits of Venus?

What is ATTRACTION?

ductor, is attracted by it. This is termed the *attraction of electricity.* The particles of matter in solid bodies, commonly adhere together in a greater or less degree. This is called the *attraction of cohesion.* Bodies in general, appear to have a tendency towards each other; this general tendency, is called the ATTRACTION OF GRAVITATION.

Indistinct views, of the manner in which the *attraction of gravitation* is manifested in the material universe, appear to have been possessed by Copernicus, Kepler, Hooke, and others. But the genius of NEWTON, was destined to develope its admirable simplicity and omnipotent energy, and thus immortalize his own name.

Reclining under a fruit tree, and witnessing the fall of an apple the *fortunate perhaps* entered Newton's mind; 'Perhaps that same principle which made the apple fall extends to the Moon and binds it in its orbit. This *mere hypothesis* as it was at the first, prepared the way for him, sometime afterwards, to unfold the sublimest truths of the sublimest of the sciences.

Here may be announced the *laws of gravitation. Equal quantities of matter, at equal distances, have equal attraction: but attraction diminishes, as the squares of the distances increase.*

Some illustration may be useful. Call the distance, from the centre to the surface of the Earth, in round numbers, 4 thousand miles. The Earth's semi-diameter now constitutes an *unit,* and call that *unit* one pound weight. Remove that one pound, a second semi-diameter from the Earth's centre, or 4 thousand miles from its surface. Twice two are four. Its tendency to the Earth, would be ¼ what it was at its surface. Remove it another 4 thousand miles, and its tendency would be ⅑ as great as at the Earth's surface, for 3 times 3 are 9.

What different kinds are there?

By whom were the laws of attraction developed? What are they? How illustrate them?

Remove it to the orbit of the Moon, its tendency would be $\frac{1}{3600}$ part as great as at the surface; for the Moon is 60 semi-diameters of the Earth distant from it, and 60 times 60, are 3600.

The semi-diameter of the attracting body, is to be used as an *unit* in determining the power of its attraction at given distances.

By the laws of gravitation, it is estimated that if no force were felt at the Moon but the attraction of the Earth, it would be drawn to its primary in less than 5 days. Were no force but this *centripetal force*, acting upon the planets, Mercury would be drawn to the Sun in about 15 days, Venus in 40 days, the Earth in 65 days, Mars in 121 days, the Asteroids in less than 1 year, Jupiter in about 2 years, Saturn in about 5 years, and Herschel in about 15 years, and the Comets from 1½ to 100 years.

CHAPTER XIX.

CENTRIFUGAL FORCE.—DENSITIES OF THE SUN AND PLANETS.

In Natural Philosophy, one essential property of matter is called *inertia*. That is, if matter be supposed to exist in a state of rest, it must forever remain at rest, unless some force from *without itself* should put it in motion; or if in motion, it would move in a straight line forever, if no force *without itself* operated to prevent the continuance of such motion. How irresistible then the evidence, that the motions of the material universe were not self-originated; but are the designs of Infinite Wisdom, and the impulses of Omnipotent Goodness. Conceive the Earth, with all its kindred bodies in the solar system, when created, to have

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With no counteracting influence, how soon would attraction draw Mercury to the Sun?—Venus?—the Earth?—the other planets?—the comets?

What is *inertia?* From known properties of matter, what moral conclusion seems unavoidable?

received from the Almighty Architect only that energy for movement called *attraction;* how soon must all the planets and comets of this system, have been drawn by their centripetal forces, to one common centre and one entire mass. But that energy which inscribed the law of attraction on material worlds, gave other displays of Omnipotence. A mighty impulse was imparted to the Sun, causing it to turn on its axis and impelling it in space; astronomers know not in how vastly extended an orbit. The same energy, imparted to Mercury a force acting at right angles with the centripetal force which should balance it. This balancing force is called the *centrifugal force,* because it tends to make the body fly from the centre. And as the attractions of the Sun, are more powerful at 37 millions, than at 95 millions of miles, the centrifugal force, to balance the centripetal, is more powerful than at the Earth, causing Mercury to revolve in its orbit, with the wonderful velocity of 108 thousand miles the hour. See Plate v. Figures 4 and 5.

When the *centrifugal force* was given to the planets, it appears to have been given to the *centres* of the *secondaries,* causing one rotation on their axes, while they revolved once round their primaries. But with the primaries, the force seems to have been applied not to their centres, but to their surfaces; giving them double motion, one on their axes, the other round the Sun.

DENSITIES OF THE SUN AND PLANETS.

THE practicability, and methods, of estimating the densities of the Earth, and even of remote worlds, can now be understood.

What is the *centripetal force ?* What the *centrifugal force ?* Why will Mercury revolve with greater velocity than the Earth ?

How does it appear that the centrifugal force was imparted to *secondaries ?*—to *primaries ?*

From patient and protracted investigations, it is estimated, that the mean density of the whole Earth, is about 5 times as great as water; that is, it would weigh five times as much, as if it were composed wholly of pure water.

Numerous and careful experiments were made, on the mountain Schehallien in Scotland, by Dr. Maskelyne, with a plumb line, to determine the attraction of the cubic miles in the mass of that mountain, compared, with the attraction of all the cubic miles of the Earth. The influence of that mountain on the plumb line, led to the conclusion that the density of the Earth is 4½ times greater than water. But Maskelyne called the mean density of the mass of matter in Schehallien only 2½, while Professor Playfair, has since estimated its mean density at 2¾, which will make the density of the Earth, 5. Experiments by Cavendish, make it a fraction more than 5. And it is a remarkable fact, that the most recent experiments, best agree with Newton's own *theoretical opinions* on this subject.

The density of the Earth being known, the degree of attraction it exerts on the Moon at 240 thousand miles distance, requires a *centrifugal force* to balance it, which causes that satellite to revolve round its primary in 27⅓ days. Jupiter's nearest satellite is about the same distance from its primary as the Moon, but that revolves in 1 day and 18½ hours, therefore, the attractions of Jupiter are much stronger than those of the Earth, proving it has more than 300 times as much matter;

What is the estimated density of the Earth?

Who made experiments in Scotland for this purpose? What was his estimated density of the Earth? What did he call the density of Schehallien? What is Professor Playfair's estimate? What infercrence results from it? What is Cavendish's estimate? What Newton's theory?

If with five times the density of water, the Earth attracts the Moon at 240 thousand miles distance, so much as to require a *centrifugal* force, which should propel it round the Earth in 27⅓ days, how much more matter must there be in Jupiter, since the nearest satellite revolves in 1 day and 18½ hours?

but when the bulk of that planet is considered, it is found, that the mean density of Jupiter is only $\frac{1}{4}$ that of the Earth, or $1\frac{1}{4}$ that of water.

When the distances and periods of revolution, of Jupiter's other satellites are correctly estimated, each gives the same result in the density of that primary. By a similar process the densities of Saturn and Herschel can be estimated.

It is easy to perceive, that by this process the density of the Sun can be found. The *attraction* it exerts, in proportion to its magnitude, is balanced by centrifugal forces in the relative velocities of planets, more near, and more remote from it, equal to a density $1\frac{2}{15}$ that of water.

The densities of *planets* which have no satellites, are best learned by accurate observations, of their attractions on other members of the solar system.

CHAPTER XX.

ORBITS OF THE PLANETS.—MUTUAL ATTRACTIONS.

When theories are substituted for a careful investigation of facts, error will be perpetuated, and truth remain undiscovered. Copernicus and Galileo, considered the orbits of all the heavenly bodies perfect circles, the circle being the simplest curve line. Facts have overturned that theory, and proved all their orbits to be elliptical.

Kepler, by a patient observation of the motions of Mars, found they could not be reconciled with that theory. He then supposed the orbit of that planet an ellipse, with the Sun in its centre.

Knowing the bulk of Jupiter, what then must be its density? Will a similar process determine the densities of other planets and of the Sun?

What was once supposed to be the forms of the orbits of the planets? Who discovered their true forms?

This did not agree with accurate observations of its *direct*, *retrograde* and *stationary* appearances. His next hypothesis was *fortunate.* He supposed the orbit of Mars an ellipse, with the Sun in one of its foci. Observations confirmed this as truth.

To draw a circle, one leg of the dividers is stationary, the other is turned round it. To draw an ellipse, or *oval figure*, one end is drawn with a leg stationary at one point, and the other end with a leg stationary at another point. These stationary points are the foci of that ellipse. The distance between the centre of an ellipse and one of its foci, is called its eccentricity.

Kepler had the honor to discover, that the orbits of ALL the planets are elliptical, having the Sun in their lower focus. Their eccentricities may be seen in the tabular view of the Solar system, page 29.

Mercury's orbit, having an eccentricity of 7½ millions of miles, will have its *perihelion*, 15 millions of miles nearer to the Sun, than its *aphelion.* The eccentricity of the orbit of Venus, being only half a million of miles, its *perihelion* varies but 1 million of miles from its *aphelion.* Addition, or subtraction, of their respective eccentricities, *to*, or *from*, their respective mean distances, will give the *aphelion*, and *perihelion*, distances of all the other planets.

The eccentricity of the Earth's orbit, is 1 million and a half miles; making its *perihelion* distance about 3 millions of miles less than its *aphelion* distance from its centre of motion.

This is proved from the Sun's disc having about 1′ greater *apparent* diameter, the beginning of January, than at the beginning of July; and by the shorter period, which elapses between the autumnal equinox and the vernal, than between the vernal and the autumnal; owing to the Earth's greater velocity in its orbit, when nearest the Sun.

Two forces, which exactly balance each other at right angles, when operating in an ellipse with the *centripetal force* in one of the foci, will produce

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What is an *ellipse?* What its *foci?* What its eccentricity? When is a planet in its *aphelion?* When in its *perihelion?* How can the elliptical form of the Earth's orbit be proved? What is its eccentricity?

accelerated motion, from the *aphelion point* to the *perihelion point,* and *retarded* motion from the perihelion to the aphelion.

Kepler discovered, that *lines* drawn from each of any two planets to the Sun, would pass over equal areas of space in equal times, and that the same is true respecting *any* planet at unequal distances from its centre of motion. This fact gave him a key to the proportionate distances, among the planets.

Kindred laws are found to be governing the comets, though moving in orbits vastly more elliptical than the planets. The eccentricities of comet's orbits, vary from 1 million and a half, to more than 6 thousand millions of miles.

MUTUAL ATTRACTIONS.

While the Sun attracts the planets, they attract the Sun. If *all* the other planets were in a direct line between Herschel and the Sun, that luminary would be attracted, almost the whole of its diameter towards them.

When the motion of one planet, in its orbit, is forward of another, its attraction will accelerate the motion of the planet that is following; but its own velocity will be retarded by the other.

Primary planets, not only affect the motions of each other, and of their own satellites, but they, and their satellites, affect the motions of other

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If two forces balance each other at right angles, when will there be accelerated motion?

What other discovery did Kepler make? What is its great utility.

How much does the eccentricity of the orbits of the comets vary? What is said of mutual attractions among the heavenly bodies? When will the motion of a planet be accelerated?—When will it be retarded?

satellites. More than 50 disturbing attractions, are to be taken into the account, in *constructing tables*, from which, the Moon's *true* place, can be known with *perfect* accuracy.

The Moon's orbit is elliptical, and its attractions, cause the Earth to revolve round their common centre of gravity, 2000 miles distant from the primary. See Plate v. Figure 6.

The Moon's perigeee, and nodes, change their places, and make one complete revolution round the Earth, in something more than 18 years. Some general correspondence, between eclipses, and harvest Moons, will, therefore, occur every 19th year.

CHAPTER XXI.

SPHEROIDAL FORMS OF THE PLANETS.—ZODIAC.—CAUSE OF THE PRECESSION OF THE EQUINOXES; AND NUTATION OF THE EARTH'S AXIS.—NEW STYLE.—DIMINISHING OBLIQUITY OF THE ECLIPTIC.

When we see a globe in motion, on an axis, it becomes at once apparent, that its equatorial surface, will revolve through a greater portion of space, in a given time, than any intermediate point between that and either pole. Conceive of a globe, called into existence, with so much fluidity of matter, that its form might easily be changed, and let it be set in motion on its axis, it would not remain

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How many disturbing influences must be considered to construct tables of the Moon's place with *perfect accuracy?* What is the form of the Moon's orbit?

How long a period is required for a revolution of the Moon's nodes? What consequence follows?

What is obvious with a globe in motion?

spherical, but become more elevated at its equator and most depressed at its poles; because, the particles of matter near its equator, would have the most *centrifugal force*, and those near its poles, the least. The degree of velocity, in its equatorial motion, joined to its density, would determine the degree in which it would become spheroidal.

We might expect, therefore, that Saturn would be more flattened at its poles than Jupiter, this last, more than the Earth, and Mercury still less. Observation confirms this theory.

It is not necessary to suppose, that the planets *have acquired* their spheroidal forms by long rotation on their axes, any more than it is needful to suppose, that the first oak or the first acorn, were as long in acquiring their specific forms as their successors. We choose rather to believe, that the Creator launched the planets into the heavens with essentially the same forms which laws then inscribed upon them, are adapted to perpetuate.

In one part of the orbit of Saturn, the Sun is 30 degrees north of its equator. The squares of the distance, between the Sun and the rings of Saturn, are less, than between the Sun and the planet itself; consequently, those rings will be attracted north, and the Sun in passing to the southern hemisphere, will be vertical over the centre of the rings, sooner than over the Equator of Saturn. Similar effects, will attend the Sun's influence in the opposite hemisphere. These remarks, will aid in the illustration of phenomena in the heavens, resulting from the same cause, in its operation on the spheroidal form of the Earth.

To render this subject intelligible, there is occasion to describe an imaginary belt in the heavens.

If its matter could easily change its position, what form would it take? What causes are to be considered in producing a spheroidal figure?

Which of the planets is most spheroidal? Is it necessary to suppose the planets have acquired their form from their rotation? Why not? How broad is the torrid zone in Saturn? What influence will the Sun's variation north and south have on the position of the rings?—and on the Equator?

THE ZODIAC.

THE Sun's *apparent annual path*, and the *real orbit* of the Earth among the stars, is in the Ecliptic, an imaginary line, in the centre of a zone in the heavens, called the ZODIAC.

This zone is 16° broad, contains the orbits of all the planets except 3 of the Asteroids, and is divided into 12 equal parts, called the 12 signs of the *Zodiac.*

The names, and characters, of the 12 signs, with the time of the Sun's entrance into them, are as follow:

1. Aries, ♈, or the Ram; March 20th.
2. Taurus, ♉, the Bull; April 20th.
3. Gemini, ♊, the Twins; May 21st.
4. Cancer, ♋, the Crab; June 21st.
5. Leo, ♌, the Lion; July 23d.
6. Virgo, ♍, the Virgin; August 23d.
7. Libra, ♎, the Balance; September 23d.
8. Scorpio, ♏, the Scorpion; October 23d.
9. Sagittarius, ♐, the Archer; November 23d.
10. Capricornus, ♑, the Goat; December 23d.
11. Aquarius, ♒, the Waterman; January 20th.
12. Pisces, ♓, the Fishes; February 19th.

The first six, are called *northern* signs, lying on the north side of the Equator; and the last six *southern*, lying on the south side.

The signs ♑, ♒, ♓, ♈, ♉, ♊, are called *ascending*, because the Sun approaches our north pole, while it passes through them; and ♋, ♌, ♍, ♎, ♏, ♐, are called *descending*, the Sun receding from our pole, as it passes through them.

What is the Zodiac? How broad? How many signs in it? Which signs are called northern? Which southern? Which ascending? Which descending?

PRECESSION OF THE EQUINOXES.

The number, and the names of these *signs*, will be recognized at once, as the same with the *constellations* of the Zodiac. They, doubtless, had a common origin, and their places were together more than 2000 years ago; but they now vary more than 30°. Where the Sun's place among the stars, is the 20th of March, or the vernal equinox, is called the beginning of the sign Aries. If the Sun and Moon were always over the Equator, the solar, and the siderial year, would be, alike. When the Sun is at the summer solstice, his attraction on the elevated matter of the Earth at its Equator, being greater than if it were a perfect sphere, affects the position of this planet, to make the Sun cross the Equator, at the autumnal equinox, sooner than it would otherwise do. A similar effect, is produced in the southern hemisphere, in our winter. The attraction at the south, makes the vernal equinox occur sooner. The arrival of the Sun, at the vernal equinox, *precedes* its complete apparent revolution in the Ecliptic, by 50″ of a degree, or 20′ of time. Hence, it is called the PRECESSION OF THE EQUINOXES. In about 26 thousand years, the Sun's place among the stars, at the vernal equinox, will have advanced from west to east, quite round the heavens, carrying the signs with it.

When had the signs and constellations of the zodiac a common location? How much do they now vary? How is the beginning of the sign Aries reckoned? When the Sun is at the summer solstice, what effect has it on the elevated matter at the Equator? What effect when at the winter solstice? How much does the vernal equinox each year PRECEDE the arrival of the Sun at the same point of the Ecliptic? What is the length of the great celestial period?

The constellations of the Zodiac, remain immoveable, and while the sign Aries is 50 seconds each year farther east, it is obvious, that it will be advancing through the stars of Pisces and Aquarius quite round the Zodiac. As the Moon revolves near the plane of the Ecliptic, it will exert a similar influence, which affects the return of the equinoxes.

NEW STYLE.

HERE, we may consider the difference between a *siderial*, a *solar*, and a *Julian* year. A *siderial* year is the time required for the Sun to perform a complete revolution in the ecliptic; which is 365*d.* 6*h.* 9′ and 11½″. The *solar* or *tropical* year is from one vernal equinox to another; which is 365*d.* 5*h.* 48′ and 48″. A *Julian*, or *civil* year, is either 365 or 366 days.

To reckon time by *Julian* years, one day is added to February every fourth year; which is called *Bissextile*, or Leap year. This being about 11 minutes longer than the solar year, would gradually change the times, both of the equinoxes, and the solstices. Pope Gregory XIII. reformed the calendar, and in 1752, the British Parliament introduced NEW STYLE, into England and all her colonies, by calling the 2d of September, the 13th of September, and changing the beginning of the year from the 24th of March, to the 1st of January.

This will explain the reason, why some years in history, directly after the adoption of New Style, were written January, 1757—8. According to Old Style 57; to *New* 58.

While 11 days were thrown out of the calender, it was determined, that the first *leap* year in each

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What other cause is affecting the return of the equinoxes?

What is the difference between a *siderial* year, a *solar* year, and a *Julian* year? What is NEW STYLE? When adopted by the English? What measure is to be adopted to keep the *vernal* equinox from variation?

century, for three centuries in *four*, should be thrown out; or called a common year. This mode of reckoning, will prevent the vernal equinox from varying, one day, in twenty thousand years.

DOMINICAL LETTER.

The first 7 letters of the alphabet are commonly placed in the annual almanacs, to show on what days of the week the days of the months fall throughout the year. And because one of those 7 letters must necessarily stand against Sunday, it is printed in a capital form, and called the Dominical letter: the other six are changed to figures.

When January begins on Sunday, A is the Dominical, or Sunday letter. If it begins on Monday, B is the Dominical letter. If on Tuesday, C, &c. till the series of letters of the alphabet are used answering to the same days of the week.

Suppose the Dominical letter be required for the year of Christ 1835, new style, I look for 1800 at the head of the Dominical letter table, on the next page, and for 35 at the left hand of the same table; and in the angle of meeting, I find F, which is the Dominical letter for that year.

There are always two Dominical letters to the leap-year, the first of which is used till the 24th of February, the last for the following part of the year.

How can the Dominical letter be found for any given year?

TABLE *for finding the Dominical Letter for 2400 years.*

After Christ.				Hundreds of Years.			
Years less than an hundred.				100 500 900 1300 1700 2100 C	200 600 1000 1400 1800 2200 E	300 700 1100 1500 1900 2300 G	400 800 1200 1600 2000 2400 B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	E D	F E
9	37	65	93	F	G	C	D
10	38	66	94	E	A	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

NUTATION OF THE EARTH'S AXIS.

The attraction of the Moon, on the elevated matter of the Equator, is slightly affecting the parallelism of the Earth's axis. That is, the north pole does not point, precisely, in the same direction in the heavens one year as another, but varies with the variation of the Moon's nodes, and points of apogee, and perigee. The greatest extent of their variation, is less than 19″ of a degree, and is periodical in between 18 and 19 years. This may be called the NUTATION OF THE EARTH'S AXIS.

DIMINISHING OBLIQUITY OF THE ECLIPTIC.

Complicated attractions, are affecting both the equinoxes, and the angle which the Ecliptic makes with the Equator. Consequently, for some thousands of years, the obliquity of the Ecliptic has been diminishing. More than 2000 years ago, it was found by observation to be about 23° 51′. Later observations have proved it diminishing, till it is now a trifle less than 23° 28′. From these premises, the conclusion was once drawn, that the *torrid zone* would continue to have its dimensions contracted, till the Sun should be vertical the whole year, at the Equator. But La Place asserts, that it admits of mathematical demonstration, that this variation of the obliquity of the Ecliptic is confined within narrow limits, and can never exceed 2° and $\frac{7}{10}$ of a degree. Science thus unintentionally confirms the promise, that summer and winter, seed-time and harvest, shall not cease.

What is the NUTATION OF THE EARTH'S AXIS?

How much has the obliquity of the Ecliptic diminished in 2000 years? What effect has this on the breadth of the torrid zone? What is the full extent to which this variation can arrive, according to La Place?

CHAPTER XXII.

TIDES.—METEOROLOGY.

If the Earth were at rest, and felt no influence from other material worlds, the laws of gravitation, as discovered by Newton, would keep the waters of the ocean *perfectly* spherical, as seen in Plate vii. Fig. 1. But daily experience proves that the ocean is agitated with continual ebbing and flowing, which we call TIDES.

Or if the Earth had no motion on its axis, and the Moon no revolution round it, the waters of the ocean would become, and remain elevated directly under the Moon; as seen in Plate vii. Figure 2. Consider the Earth as having a diurnal rotation on its axis from west to east, a tide would pass to the west every 24 hours. The Moon, however, is falling back to the east in its orbit so much, that it comes to the meridian about 50 minutes later each day, therefore the tides will be later. The full effect of the Moon on the water, in accumulating it in tide, is not felt instantly; consequently, the tide under the Moon becomes highest some hours after that luminary has past the meridian. This accounts for *one* tide in 24 hours and 50 minutes.

If the Earth felt no influence from other material worlds, and had no motion, what form would the waters of the ocean always exhibit?

What other appearance is daily witnessed? What would be the state of the water, if the Earth had no rotation and the Moon no revolution? If one of these motions existed without the other, what would be the result. How much later is the Moon in the meridian each evening? Why does not a TIDE acquire its full elevation when the Moon is in the meridian?

When treating of gravitation it was remarked, that its power diminishes as the squares of the distance increase. While the Moon attracts the water nearest to it, more than the solid part of the Earth more distant, it will attract the fluids *less* on the opposite side, than it does the intermediate solids; and this will cause the water to rise in the nadir, when the Moon is in the zenith. This may be illustrated by Plate vii. Fig. 4. When the water is elevated two sides, it must be depressed on the sides at right angles. The rotation of the Earth will, consequently, give two elevations and two depressions of the water, in 24 hours and 50 minutes.

It may also be remarked, that the motions of the Earth on its axis, round the centre of gravity between that and the Moon and even in its orbit round the Sun, *may possibly* all contribute to impart most centrifugal force to the water on that side of the primary, which is opposite to the secondary, and thus a tide would be raised.

When the Moon is over the Equator, those two tides would be of about equal elevation in any given place, other things being equal. But if the Moon were 28½° north of the Equator, northern Latitudes would have the highest tide with the Moon in the meridian, and that corresponding tide would pass over the southern hemisphere 12½ hours after. When the Moon is south of the Equator, the reverse of this would be true. The higher the Latitude, the more *unequal* these two

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What causes two *tides* in 24¾ hours?

When the Moon is highest in the northern hemisphere, which tide with us will be the most elevated? Which, when the Moon has greatest southern declination? How often will the tide then rise at the poles? What effects in tides, result from the Moon over the Equator between the polar circles?—at the poles?

tides. At the poles *no tide* would rise when the Moon was over the Equator. At other times one tide would occur in 24 hours and 50 minutes; and that would be highest, when the Moon was most remote from the Equator.

Thus far, the influence of the Moon ALONE, has been considered in producing tides. But the Sun raises tides likewise. At the change of the Moon, the influence of both luminaries will be combined, and the tides will rise very high. See Plate vii. Fig. 4. A similar effect results from their influence when in opposition, as seen in Plate vii. Fig. 6. These are called *spring tides*, and the Moon's place *syzygies*. When the Moon is in *quadrature*, as seen in Plate vii. Fig. 5, the influence of the Sun will diminish the tides. Those are called *neap* tides.

The swell of the ocean, is not greatest with the Moon in the meridian, but a few hours afterwards, and the *spring tides* do not occur *precisely* at the *change* and *full*, but about the *third* tide after, and the neap tides, as much after the quadratures.

The Moon's distance from the Earth, and the distance of both from the Sun, are very variable, and these variations affect the tides.

When the Moon is in conjunction, the attraction of the Sun is stronger on that, than on the Earth; when in opposition, this attraction is strongest on the primary. In both cases, it tends to separate them. At the quadratures, the effect of the Sun's influence, is to bring the Earth and Moon nearer together.

What other cause but the Moon's influence as affecting the tides? When will the joint influence of the Sun and Moon produce the highest tides? What are these called? Do they occur exactly at the Moon's syzygies? What are NEAP TIDES? When will they occur?

In what manner are the varying distances of the Earth from the Sun, and Moon from the Earth, affecting the tides?

Illustration of the Tides

Fig. 1.

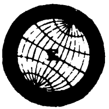


Fig. 2.

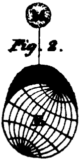


Fig. 3

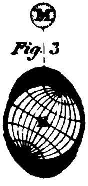


Fig. 4.

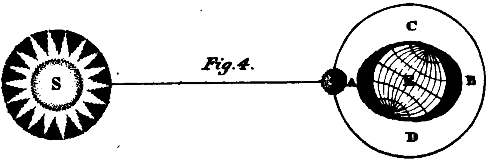


Fig. 5.

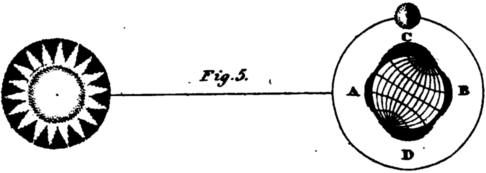
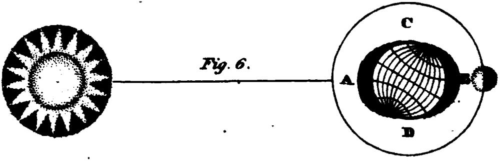
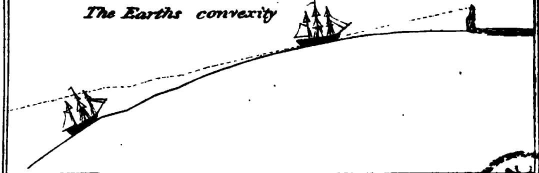


Fig. 6.



The Earths convexity



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Such influence from the Sun will be strongest, when the Earth is in its perihelion, in January, and least soon after the summer solstice. The Moon's orbit is elliptical; and from the retrograde motion of its nodes, its perigee may be either at the change, or at any intermediate point of its revolution. It will be obvious that all these diverse circumstances of the Sun and Moon, will diversify the elevation of the tides.

Local causes are operating to produce a great diversity in the height to which tides rise, when rolled into bays and mouths of rivers. In the bay of Fundy, actual observation has proved that tides rise at some points to the enormous height of 70 feet. At Boston, the unit of altitude in the tide is 11¼ feet; at New-York, 5 feet; at Charleston, S.C. 6 feet. Storms, trade winds, currents in the ocean, obstructions from capes or islands, are all affecting the power and elevation, which the swell of the tide may have, at different points of contact with the land. But on every rock, and every sand bank, which for unknown ages has been lashed by the surges of this swelling and tempest tossed element, the devout mind finds the inscription from an invisible power, "*hitherto shalt thou come and no farther, and here shall thy proud waves be stayed.*"

As the atmosphere is more easily agitated than water, doubtless both the Sun and Moon raise *tides* in that. But this medium is too elastic and subtle, for the *weather-wise*, to found predictions on the changes of the Moon, which may be relied on with confidence.

What is said of the operation of local causes on the tides? What is the elevation of tides in the bay of Fundy? What at Boston?—at New-York?—at Charleston, S. C. What inscription can piety read on the shores of the ocean. Are there other tides besides those of water? Can any reliance be placed on calculated changes of the weather from either the Moon's syzygies, or quadratures?

METEOROLOGY.

The term METEOROLOGY, is sometimes used to embrace *atmospherical phenomena* in general. But it is here used in its more restricted sense, as relating to METEORS.

The phenomena of *shooting stars*, as they are called in popular language, is very imperfectly understood. They are commonly at a small elevation only, in the atmosphere. In high latitudes, their appearance is most frequent, and they are supposed to be indicative of a change of weather.

But a class of bodies, denominated *meteoric stones*, have attracted much attention among mankind. Credible accounts, both ancient and modern, of the fall of large stones from the atmosphere, in different parts of the world, are abundant. The times and places of their fall, and the magnitudes of several of these, will be subjoined, after giving the following details respecting one, which fell in Connecticut, December 14, 1807.

"About half past six o'clock in the morning, the people to the north of Weston, in Connecticut, observed a fire-ball issuing from a very dark cloud. Its apparent diameter was equal to that of half, or two thirds, of the Moon; its light was vivid and sparkling, like that of incandecsent iron, and it left behind it, a pale and waving luminous train, of a conical form, and ten or twelve times as long as the diameter of its body, but which was soon extinguished. This meteor, of which the apparent motion was less rapid than that of most others, continued visible for half a minute, during which it exhibited three successive bounds, with a diminution of its lustre. About thirty or forty seconds after its extinction, there were heard during three se-

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What *two* definitions of Meteorology are given? What are *shooting stars?*

In what latitudes are they most frequent? What remark able bodies frequently fall to the earth?

What particulars can be given of the one which fell in Connecticut in 1807?

conds, three very loud reports, like the firing of a four pounder at a little distance; and these were succeeded, by a more prolonged and rolling noise. With the successive explosions, stones were darted in the environs of Weston, and even into the town itself. These stones were found in six different places, nearly in the line of the meteor's path, and from six to ten miles distant from one another. They fell in the presence of many witnesses, some plunging into soft soil, and others breaking into fragments against the rocks on which they happened to impinge. The most entire specimen weighed 35 lbs., but a much larger one was dashed in pieces against a rock of mica-slate; and, from the amount of fragments collected, it was estimated to have weighed 200 lbs. At the moment of their fall, these stones were hot and friable; but they gradually became hard by exposure to the air. They had the black external crust of other meteorites, and the usual gray cinereous aspect within, with whitish-gray particles, of a rounded form, impacted in the mass, and a general granular texture, in which were observable, 1. Globules of the same nature with the stone, but presenting a more compact structure, a more even fracture, and under a strong light, indications of a lamellar texture, with the appearance of felspar; 2. Grains of oxyd of iron, of rust color; and, 3. Shining yellow sulphuret of iron, disseminated in very minute grains. Their specific gravity varied from 3.3 to 3.6, and their analysis, as reported by Warden, yielded,

Silica, - - - - -	41
Alumina, - - - -	1
Lime, - - - - -	3
Magnesia, - - - -	16
Oxyd of iron, - - -	30
Manganese, - - - -	1.34
Sulphur, - - - -	2.33
Chrome, - - - -	2.33
	97

The chief phenomena observed in meteoric bodies, are, 1st, Their sudden appearance; 2d, Their rapid motion, with only a slight degree of inclination to the horizon; 3d, The loud and whizzing noise that attends their descent; 4th,

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By whom was there an analysis of a portion of that made? What was the result?

The violent explosion that follows their bursting; 5th, The marks of fusion which they bear, the intensity of their heat, and its gradual diminution; 6th, The similarity of internal composition, and of external appearance, observed in every one of them; 7th, Their peculiar nature, which resembles that of no other terrestrial body, whether natural or artificial.

Some of the meteorites are of small dimensions, and have fallen in the form of a shower; but there are some on record of considerable magnitude, among which the following have been selected as examples.

A stone weighing 260 lbs. at Enisheim, in Germany, November 7, 1492.

A stone weighing 72 lbs. near Larissa, in Turkey, January 6, 1706.

A stone weighing 20 lbs. near Padua, in 1510.

A stone weighing 59 lbs. in Provence, Nov. 27, 1627.

A stone weighing 56 lbs, in Yorkshire, Dec. 13, 1795.

One stone of 200 lbs. and one of 300 lbs. near Verona, in 1762.

This condensed view of the sublimest field in the whole range of the sciences, may be appropriately CONCLUDED in the following lines from an elegant English poet.

These are thy glorious works, Parent of good,
Almighty, thine this universal frame,
Thus wondrous fair; thyself how wondrous then!
To us invisible, or dimly seen
In these thy lowest works; yet these declare
Thy goodness beyond thought and pow'r divine.

What are the usual attendants of the fall of meteoric stones? Where, and when, have others fallen? How is this chapter concluded?

CHAPTER XXIII.

EXPLANATION OF ASTRONOMICAL TERMS.

Aberration of light, arises from the motion of the Earth combined with the motion of light.

Accelerated motion, is that in which the velocity is continually increasing from the continued action of the moving power.

Aeronaut, a person who navigates the air in a balloon.

Altitude of any celestial body, is its nearest distance to the horizon.

Analogous, having a relation or agreement to any thing else.

Angle, the opening of two lines meeting in a point.

Annual, occurring yearly.

Annular, resembling a ring.

Aphelion, that point in the orbit of a planet, in which it is at its greatest distance from the Sun.

Apogee, that point in the Moon's orbit remotest from the Earth.

Aqueous, watery, consisting of vapor.

Arc, a portion of the circumference of a circle.

Atmosphere, that collection of vapors, or body of air, which surrounds the Earth.

Attraction, a property of matter by which bodies are made to approach towards each other, without any sensible agent either drawing or impelling them.

Aurora, the morning twilight which begins to appear when the Sun is about eighteen degrees below the horizon.

Aurora Borealis, meteors observed in the north, supposed to be occasioned by electricity.

Axis of the Earth, or other planet, or of the Sun, an imaginary line passing through its centre, from one pole to the other, round which it is supposed to perform its rotations in stated periods.

Caloric, a modern term to denote that agency by which the phenomena of heat are produced.

Centrifugal force, that force by which any revolving body, has a tendency to fly off from the centre of motion.

Centripetal force, that force by which any revolving body is made to tend towards the centre of its orbit.

Chronometer, a term commonly used for a machine so constructed, as to measure a small portion of time with the greatest accuracy.

Circumnavigate, to sail round.

Colures, two circles passing through the poles, and cutting the Equator at right angles; one passes through the 1° of Aries and the 1° of Libra, and is called the Equinoctial Colure; the other through the 1° of Cancer and the 1° of Capricorn, and is called the Solstitial Colure.

Conical, terminating in a point.

Conjunction, is when two objects seen from the Sun, or the Earth, appear in the same point of the heavens, or answer to the same degree of the ecliptic.

Constellation, a number of stars which are imagined to form any particular animal or figure.

Convergency, tendency to a common point.

Cosmical rising and **setting**, is when a star rises or sets at Sun-rise.

Corruscation, a sudden, transient gleam of light.

Convex, curved, as the outside of a globular body.

Cube, any number multiplied twice by itself.

Declination, the distance of a celestial body from the equinoctial.

Degree, the 360th part of every circle.

Density, strictly speaking, denotes closeness of particles, but in mechanical science, it is used as a term expressing the quantity of matter in one body, by the quantity of matter of the same bulk in another body.

Diagram, a mathematical scheme.

Diameter, is the line, which passing through the centre of a circle, divides it into two equal parts.

Digit, the twelfth part of the apparent disc of the Sun or Moon.

Disc, the face of the Sun or Moon, which on account of the great distance of the object, appears flat, or like a plane surface.

Diurnal, belonging to the day.

Divergency, an apparent receding of two or more objects from each other.

Eccentricity, the distance between the centre of an ellipse and either of its foci.

Eclipse, an obscuration of light from one body by the interposition of another.

Ecliptic, a great circle of the sphere, in which the Sun always appears to move; so called because eclipses generally happen when the Moon is in, or near this circle.

Emersion, the time when any planet that has been eclipsed begins to recover its light again.

Equation of time, is the difference between solar time, and mean, or clock time.

Equator, a great circle which separates the northern from the southern hemisphere.

Equinoctial, a circle in the heavens corresponding to the equator on the Earth.

Equinoxes, the two points where the Ecliptic cuts the Equator. They are so called, because when the Sun is in either of these situations, the days and nights are equal to each other.

Foci, the plural of focus, are the two points in the transverse axis of a planet's orbit, distant from each other, twice the extent of the eccentricity.

Galaxy, the milky way.

Geocentric place, the place of a celestial body as seen from the Earth.

Gibbous, protuberant, convex; applied to the Moon between the quadrature and full. It is also applied to some of the planets.

Gravitation, tending towards the centre.

Heliocentric place, the place of a celestial body as seen from the Sun.

Heterogeneous, literally imports something of a different nature, in opposition to homogeneous.

Hemisphere, the half of a globe or sphere.

Horizon, a great circle of the sphere, dividing the Earth into two equal parts, its poles are the zenith and nadir.

Hypothesis, a supposition, a system formed upon some principle which has not been proved.

Immersion, the moment when an eclipse begins, or when a planet enters into the dark shadow of the Moon.

Inclination, the angle which the orbit of one planet makes with that of another, or with the Ecliptic.

Inertia, a passive principle, by which bodies persist in a state of rest or motion, unless prevented by some external force.

Latitude, the nearest distance of any place on the Earth to the Equator.

Latitude of a planet, or star is its nearest distance to the plane of the Ecliptic.

Line of the apsides, a line joining the aphelion and perihelion of a planet.

Longitude of a place, is its distance, east or west, from the first meridian, reckoned in degrees, minutes, &c. upon the Equator.

Longitude of a star, or other heavenly body, is its distance east from the beginning of the sign Aries, reckoned in degrees and minutes on the Ecliptic.

Lunar, relating to the Moon.

Lunar aspects, are those which the Moon makes with any of the other planets; as when she comes in opposition, trine, quartile.

Maculæ, dark spots appearing on the face of the Sun, Moon, and some of the planets, being contra-distinguished from Faculæ, which are bright or shining spots, that by means of the telescope are, sometimes, to be seen on the face of the Sun, &c.

Mean motion of a planet, is that which would take place it it moved in a perfect circle, and passed through equal portions of it every day.

Meridian, a circle passing through any particular place and the two poles.

Micrometer, an instrument by which the apparent magnitudes of objects viewed through telescopes, or microscopes, are measured with great exactness.

Microscope, an optical instrument, by means of which very minute objects are represented much larger, and viewed distinctly at small distances.

Minute, the 60th part of an hour, or degree.

Nadir, that point in the heavens, which is directly opposite to the zenith, or immediately under out feet.

Nebulæ, are telescopic stars, having a cloudy appearance.

Nodes, the two points where the orbit of a planet, or the Moon, intersects the plane of the Ecliptic.

Notanda, things to be noted, or observed.

Nucleus, a term used by some astronomers for the head of a comet, and by others, for the central parts of the planets.

Nutation of the axis of the Earth, a libratory motion occasioned by the attraction of the Sun and Moon, upon the protuberant matter of the Equator.

Oblique, indirect, or inclined.

Parallax, the angle the semidiameter of the Earth forms with a celestial body.

Penumbra, is the shadow where a part of the Sun's rays are intercepted.

Perigee, the point in the Moon's orbit nearest to the Earth.

Perihelion, the point in a planet's orbit nearest to the Sun.

Phases, the several appearances of the Moon and planets, according as a greater or less part of their illuminated hemispheres are presented to our sight.

PHOSPHORIC, luminous.

PLANE of a planet's orbit, is the imaginary surface in which it lies; passing through the centre of the planet it extends indefinitely into the heavens.

PLANETARIUM, an instrument made use of for showing the phenomena of the planets.

PLEIADES, the seven stars, a prominent cluster of stars in Taurus.

POLAR CIRCLES, two small circles drawn round the Earth from east to west, parallel to the Equator, about 23° 28′ from the poles; the northern called the Arctic, the southern the Antarctic circle.

POLES of the world, extremities of the Earth's axis.

PRECESSION OF THE EQUINOXES, a slow motion of the two points where the Equator intersects the Ecliptic, which are found to move backwards, about 50 seconds a year, and a whole circle in 26000 years.

QUADRANT, the fourth part of a circle; or an instrument used for measuring angles and taking the altitude of the heavenly bodies.

QUADRATURES, or QUARTERS, those phases of the Moon which take place between the conjunction and opposition, and between the opposition and conjunction.

RADIATION, the act of a body diffusing rays all around and from a centre.

RADIUS, semi-diameter of a circle.

REFRACTION, bending of the rays of light in passing through mediums of different densities.

RECTILINEAL, in a right line.

RETARDED MOTION, continually decreasing velocity.

RETROGRADE, an apparent motion of the planets in some parts of their orbits where they seem to go backwards.

REVOLUTION, is that motion by which the heavenly bodies, in a certain time, return again to the same points of their orbits.

ROTATION, the motion of any heavenly body round its axis.

SECOND, the 60th part of a minute.

SIDERIAL DAY, the time which elapses between a star's appearing twice on the same meridian.

SIDERIAL YEAR, the time which elapses between the Sun's appearing twice in conjunction with the same star.

SOLSTICES, the time the Sun enters Cancer and Capricorn.

SPHERE, a globe.

SPHEROIDAL, approaching to the figure of a sphere, though not exactly round.

STELLATED, decked with stars.

Stationary, that state in which a planet is when it has no apparent motion.

Strata, beds or layers.

Style, the manner of reckoning time from some particular period or remarkable event.

Syzygies, the conjunction and opposition of a planet with the Sun.

Telescopic stars, are those which are only discoverable by means of a telescope.

Transit, is the passing of an inferior planet over the Sun's disc.

Twilight, is that light which precedes the rising, and succeeds the setting of the Sun.

Umbra, the conical shadow of the Earth or Moon in an Eclipse.

Vertical, directly over head, or in the zenith.

Zenith, that point of the heavens, which is perpendicularly over our heads.

Zodiac, a zone surrounding the heavens, of about sixteen degrees broad; in the middle of which is the Ecliptic; and in which the orbits of all the planets are included except three of the asteroids.

Zodiacal light, a brightness sometimes observed in the Zodiac, resembling that of the Galaxy. It appears at certain seasons, viz. towards the end of winter, and in spring after sunset; or before his rising in autumn, and in the beginning of winter, resembling the form of a pyramid lying lengthways with its axis along the Zodiac, its base being placed obliquely with respect to the horizon. The cause of this light is yet too imperfectly understood, to pronounce on it with confidence.

Zone, a division of the Earth. There are five zones: one torrid zone, lying between the tropics; two temperate zones, between the tropics and the polar circles; and two frigid zones, between the polar circles and the poles.

☞ *The questions were intended to exhaust the topics discussed, and with few exceptions, will be found on the pages with their answers.*

APPENDIX.

PROBLEMS ON THE GLOBES, AND USEFUL TABLES

PROBLEM I.—To find the Latitude of a place. Bring the given place under the brazen meridian, and the number of degrees on it to which the place corresponds is its Latitude.

PROBLEM II.—To find the Longitude of a place. Bring the given place to the brass meridian; and the number of degrees which it cuts on the Equator, will be the Longitude of that place.

PROBLEM III.—To find the Sun's place in the Ecliptic on any given day. Look for the given day and month, on the wooden horizon, and opposite to the day will be seen the sign and degree in which the Sun is then; and this being noted on the Ecliptic, will give the Sun's place on the day required.

PROBLEM IV.—To find, at any hour, what o'clock it is at any other place. Bring the place of which the hour is known to the brass meridian; set the index to the given hour. If the place required be now brought under the meridian, the index will mark the hour at the place required.

PROBLEM V.—To find the time of the Sun's rising or setting for any given day. Rectify the globe for the Latitude of the place you are in; bring the Sun's place for the given day to the brass meridian; and set the index to 12. If the Sun's place be turned to the eastern edge of the wooden horizon, the index will shew the hour of sun-rise; and if it be brought to the western edge, the index will shew the time of sun-set. Twice the hour of the Sun's setting gives the length of the day; and twice the hour of its rising, the length of the night.

PROBLEM VI.—Given the day and hour at any place, to find those places where the Sun is then rising or setting, and on the

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How do you find the Latitude of any place on the globe? What is the Latitude of London?—of St. Petersburgh?—of Washington? (See the Tables for correcting the answers given by the Pupils.) How do you find the Longitude? What is the Longitude of Paris?—of Constantinople?—of New-York? (See the Tables that are intended to be a substitute for the usual detail of examples.) How find the Sun's place in the Ecliptic for a given day? How do you find what o'clock it now is in any given place? How can the time of the Sun's rising and setting be known for a given day?

meridian, or midnight. 1. Find the place where the Sun is vertical at the given hour. To do this, bring the Sun's place for the given day to the brass meridian; mark its declination; bring the given place to the brass meridian, and set the index to the given hour; turn the globe till the index points to 12; the degree of the Sun's declination for that day shews the place to which it is vertical at the given hour. 2. Elevate the pole as many degrees above the horizon as are equal to the Latitude of the given place; bring it to the brass meridian: the Sun rises then for all places on the western edge of the wooden horizon, and sets at all places on the eastern edge. It is noon at all places under the brass meridian, and midnight at all those under the lower part of this meridian. The morning twilight is beginning in all places 18° below the western semicircle of the horizon; and the evening twilight is ending in all places 18° below the eastern semicircle of the wooden horizon.

Problem VII.—To find the Antœci, Periœci, and Antipodes of any place. Bring the given place to the brass meridian, and observe its latitude, then under the same degree of latitude, in the opposite hemisphere you will find the Antœci. Set the index of the hour circle to 12, turn the globe half round, or until the index points to the other 12; then under that degree on the brass meridian, which is the latitude of the given place, you will find the Periœci. Under the same degree of latitude with the given place, but in the opposite hemisphere, you will find the Antipodes.

Problem VIII.—To find at what rate per hour the inhabitants of any place are carried, from west to east, by the revolution of the earth on its axis. Find by the Longitude table, how many miles make a degree of longitude in the latitude of the given place, which multiply by 15 for the answer.

Problem IX.—Any day being given, to find all those places of the earth where the sun is vertical on that day. Find the

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If the day and hour are given at one place, how determine where the Sun is then rising or setting or in the meridian?

How do you find the Antœci? How the Periœci? How the Antipodes?

How can the rate of motion per hour on any given plane be ascertained? What is the rate per hour of New-York? Boston?—Charleston, S. C.?

Over what places will the Sun be vertical the 27th of January? Over what places the 4th of August?

sun's declination (by Prob. III) for the given day, turn the globe round on its axis from west to east, and all the places on the globe, which pass under the degree of the sun's declination on the brass meridian will have the Sun vertical on that day.

PROBLEM X.—To find the length of the longest day at any place in the north frigid zone. Find the complement of the latitude of the given place, by subtracting its latitude from 90 degrees; count as many degrees on the brass meridian from the equator towards the north pole, as are equal to the complement of the latitude, and mark where the reckoning ends; turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark, find those two points of the ecliptic in the circle of signs on the horizon, and exactly opposite to them, in the circle of months, you will find the days on which the longest day begins and ends. The day preceding the 21st of June is that on which the longest day begins, and the day following the 21st of June, is that on which it ends; the number of days between these days will show the length of the longest day at the given place. [See the Table of Climates.]

THE CELESTIAL GLOBE.

The celestial globe is intended to represent the starry heavens, and their apparent motion from east to west. On it are drawn, the Ecliptic, the Equinoctial, the parallels of Latitude, the circles of declination, the meridians, the horizon, the two colures, the tropics, the polar circles, and all the constellations. In using this globe, the spectator is supposed to stand in the centre of it: hence the figure of all the constellations must be reversed, when they are to be referred to the heavens.

PROBLEM I.—To find the right ascension and declination of the Sun, or of a star. Bring the Sun, or star, to the brass meridian; the degrees on the Equinoctial, between the brass meridian and the first point of Aries, is the right ascension; and the degree on the brass meridian is the declination.

PROBLEM II.—To find the Latitude and Longitude of a star. Bring the centre of the quadrant of altitude on either pole of the Ecliptic; move the other end, till the star is at the gra-

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How can the right ascension or declination of the Sun, or a star, be found? How can the Latitude or Longitude of a star be known?

duated edge of the quadrant. The degree of the quadrant, cut by the star, is its Latitude; and the sign and degree cut on the Ecliptic, is its Longitude.

PROBLEM III.—To find the place of a star, planet, Moon, or a comet, on the globe, its right ascension and declination being given. Bring the given degrees of right ascension to the brass meridian; and under the given declension, on the brass meridian, the star, or place of the planet, will be found.

PROBLEM IV.—The day, hour, and Latitude of a place being given, to find what stars are rising, setting or culminating, &c. Elevate the pole to the Latitude of the place; bring the Sun's place in the Ecliptic to the brass meridian; set the index to 12; if the given time be before noon, turn the globe eastward, till the index has passed over as many hours as it wants of 12; and if it be afternoon, turn the globe westward, till the index has past over as many hours as it is past 12; then all the stars west of the horizon will be setting; all those east of it will be rising; those under the brass meridian will be culminating, &c.

PROBLEM V.—To find when any given star will rise, set, or come to the meridian. Elevate the pole to the Latitude of the place; bring the Sun's place in the Ecliptic to the meridian; set the index at 12; turn the globe till the given star, or planet, comes to the east of the horizon, and the index will shew the time of its rising; bring the star to the meridian, and you have the time it crosses the meridian; bring it to the west of the horizon, and you have the time of its setting.

PROBLEM VI.—To find the distances of the stars in degrees from each other. Place the quadrant of altitude on the two stars whose distance you wish to measure; so that the division marked O be on one of them, and the degrees between them will show their distance.

If the right ascension or declination of a heavenly body is given, how can it be found? How can the length of the longest day in different places within the Arctic circle be found on the globe?

If the day, the hour, and Latitude of a place be given, how find what stars will then be rising, setting, or culminating? How can it be found when any given star will rise, set, or come to the meridian? How can the distance of stars from each other be found in degrees?

PROBLEM VII.—To find the altitude of a star at any given time. Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian, and set the index at 12. Turn the globe till the index points to the time proposed. Then with the quadrant of altitude, or dividers, take the nearest distance of the star from the horizon; the number of degrees on the quadrant, or in the extent of the dividers applied to the equator, shows the altitude.

PROBLEM VIII.—Having the altitude of a star given, to know the time of night. Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian, and set the index at 12. Turn the globe till the star comes to the altitude proposed; the index will point to the hour required.

PROBLEM IX.—The Latitude of a place being given, to place the globe so as to represent the appearance of the heavens at any hour proposed. Rectify the globe for the Latitude of the place. Bring the sun's place in the ecliptic to the meridian and set the index at 12. Turn the globe eastward for the forenoon, westward for the afternoon, till the index points to the given hour. The globe will then represent the appearance of the heavens at the time proposed.

"A familiar use of the globes is recommended to the student. It will greatly improve his knowledge of geography and astronomy. It will make him more interested in contemplating the objects of the visible heavens, a delightful and innocent amusement for the evening, or the most lonely hours of night. What is much more; by observation on the celestial canopy, he must be irresistibly led from the greatness of the scenery to the contemplation of the immensity and infinite goodness of the GREAT AUTHOR." VOSE.

What is the altitude of Procyon, as seen at Washington, February 1st, at 7 o'clock, P. M. What is the altitude of Vege, as seen from New-Haven, September 26, at 2 o'clock, A. M.?

What is the time of night at Philadelphia, on the 20th of October, when the largest star of the Pleiades is 15° above the eastern horizon. What is the time of night at Boston, on the last day of August, when Arcturus is 10° above the western horizon?

What will be the appearance of the heavens at Washington, March 20th, at 7 o'clock, P. M

A Table *of the Latitude and Longitude of some of the principal places of the world.*

		Latitude.			Longitude.		
Aberdeen,	Scotland,	57°	9′	N.	2°	8′	W.
Abo,	Sweden.	60	27	N.	22	13	E.
Acapulco,	Mexico,	17	10	N.	101	26	W.
Achen,	Sumatra I.	5	22	N.	95	35	E.
Adrianople,	Turkey,	41	10	N.	26	28	E.
Aleppo,	Syria,	36	11	N.	37	10	E.
Alexandria,	Egypt,	31	12	N.	29	55	E.
Algiers,	Africa,	36	49	N.	2	12	E.
Amsterdam,	Holland,	52	22	N.	4	51	E.
Archangel,	Russia,	64	34	N.	38	55	E.
Athens,	Greece,	38	5	N.	23	52	E.
Bagdad,	Syria,	33	20	N.	44	23	E.
Barcelona,	Spain,	41	26	N.	2	12	E.
Batavia,	Java I.	6	11	S.	106	52	E.
Bergen,	Norway,	60	23	N.	5	12	E.
Berlin,	Germany,	52	32	N.	13	23	E.
Bombay I.	Indies, E.	18	56	N.	72	54	E.
Botany Bay,	New-Holland,	34	0	S.	151	20	E.
Bristol,	England,	51	28	N.	2	35	W
Brussels,	Netherlands,	50	51	N.	4	21	E.
Cadiz,	Spain,	36	31	N.	6	17	W
Cairo,	Egypt,	30	3	N.	31	17	E.
Calcutta,	Bengal,	22	35	N.	88	28	E.
Canton,	China,	23	7	N.	113	16	E.
Cape of G. Hope,	Africa,	34	29	S.	18	23	E.
—— Farewell,	Greenland,	59	38	N.	42	42	W.
Constantinople,	Turkey,	41	1	N.	28	55	E.
Copenhagen,	Denmark,	55	41	N.	12	35	E.
Damascus,	Syria,	33	16	N.	36	20	E.
Dresden,	Germany,	51	3	N.	13	41	E.
Dublin,	Ireland,	53	22	N.	6	17	W.
Edinburgh,	Scotland,	55	57	N.	3	12	W.
Geneva,	Switzerland,	46	12	N.	6	8	E.
Genoa,	Italy,	44	25	N.	8	50	E.
Ghent,	Netherlands,	51	3	N.	3	43	E.
Gibraltar,	Spain,	36	5	N.	5	4	W.
Glasgow,	Scotland,	55	52	N.	4	15	W.
Greenwich (obs.)	England,	51	28¾	N.	0	0	
Halifax,	Nova-Scotia,	44	44	N.	63	36	W.
Hamburgh,	Germany,	53	34	N.	9	54	E.
Havre-de-Grace,	France,	49	29	N.	0	6	E.

		Latitude.			Longitude.		
Hervey's I.	Society Isles,	19	17	S.	158	56	W.
Jaffa,	Syria,	32	5	N.	0	10	E.
Jerusalem,	Syria,	31	45	N.	35	20	E.
Ispahan,	Persia,	32	25	N.	52	50	E.
Kamtschatka,	Siberia,	56	30	N.	161	0	E.
Leyden,	United Provinces,	52	8	N.	4	28	E.
Lima,	Peru,	12	2	S.	76	50	W.
Lisbon,	Portugal,	38	42	N.	9	9	W.
Liverpool,	England,	53	22	N.	2	57	W.
London,	England,	51	31	N.	0	6	W.
Lyons,	France,	45	46	N.	4	49	E.
Madras,	Indies, E.	13	5	N.	80	25	E.
Malta I.	Mediterranean,	35	54	N.	14	28	E.
Marseilles,	France,	43	18	N.	5	22	E.
Mecca,	Arabia,	21	45	N.	40	15	E.
Mexico,	N. America,	19	54	N.	100	7	W
Milan,	Italy,	45	28	N.	9	14	E.
Montpelier,	France,	43	37	N.	3	52	E.
Morrocco,	Barbary,	31	0	N.	7	4	W.
Moscow,	Russia,	55	45	N.	37	46	E.
Nankin,	China,	32	5	N.	118	46	E.
Naples,	Italy,	40	50	N.	14	17	E.
North Cape,	Lapland,	71	30	N.	25	49	E.
Otaheite,	S. Pacific Ocean,	17	20	S.	149	30	W.
Panama,	Mexico,	8	58	N.	80	15	W.
Paris, (obs.)	France,	48	50	N.	2	20	E.
Pekin, (obs.)	China,	39	54	N.	116	27	E.
St. Petersburgh,	Russia,	59	56	N.	30	18	E.
Porto-Bello,	Terra Firma,	9	33	N.	79	50	W.
Portsmouth,	England,	50	47	N.	1	6	W.
Potosi,	Peru,	20	0	S.	66	15	W.
Presburg,	Hungary,	48	8	N.	17	10	E.
Quebec,	Canada,	46	48	N.	71	6	W.
Quito,	Peru,		13	S.	78	10	W.
Rio Janerio,	Brazil,	22	54	S.	42	44	W.
Salonica,	Turkey,	40	41	N.	23	7	E.
Siam,	E. Indies,	14	18	N.	100	49	E.
Torneo,	Lapland,	65	51	N.	24	14	E.
Trent,	Germany,	46	5	N.	11	6	E.
Tripoli,	Barbary,	32	54	N.	13	20	E.
Turin,	Italy,	45	5	N.	7	39	E.
Utrecht,	United Prov.	52	5	N.	5	9	E.
Vienna, (obs.)	Austria,	48	12	N.	16	22	E.
Warsaw,	Poland,	52	16	N.	21	3	E.

LATITUDE AND LONGITUDE OF SOME OF THE PRINCIPAL PLACES IN THE UNITED STATES.

The Longitudes are reckoned from Greenwich. Seats of Government are in Italic Letters.

	Lat. °	Lat. ′	Long. °	Long. ′		Lat. °	Lat. ′	Long. °	Long. ′
Albany, N. Y.	42	39	73	42	*Nashville*, Ten.	36	45	87	8
Alexandria, D. C.	38	49	77	4	Natchez, M'pi.	31	34	91	25
Annapolis, Md.	39	0	76	43	Newburyport, Ms.	42	49	70	52
Arkansas, Ark.	33	58	91	30	*New Haven*, Ct.	41	18	72	58
Augusta, Me.	44	16	99	44	*New Orleans* City, La.	29	57	90	9
Augustine, St. Fa.	29	45	81	30	*Newport*, R. I.	41	25	71	14
Boston City, Ms.	42	20	71	4	New-York City, N. Y.	40	42	74	1
Brattleborough, Vt.	42	52	72	27	Norfolk, Va.	37	12	76	42
Burlington, Vt.	44	28	73	15	Northampton, Ms.	42	16	72	40
Cambridge, Ms.	42	21	71	7	Pensacola, Fa.	30	28	87	12
Camden, S. C.	34	17	80	33	Philadelphia City, Pa.	39	56	75	11
Charleston City, S. C.	32	50	79	48	Pittsburg, Pa.	40	32	80	8
Cincinnati, Ohio.	39	6	84	27	Portland, Me.	43	39	70	20
Columbia, S. C.	33	57	81	7	Portsmouth, N. H.	43	4	70	46
Columbus, Ohio.	39	47	83	3	Princeton, N. J.	40	22	74	35
Concord, N. H.	43	12	71	29	*Providence*, R. I.	41	51	71	16
Detroit, Mich.	42	24	82	58	*Raleigh*, N. C.	35	47	78	48
Dover, Del.	39	10	75	30	*Richmond City*, Va.	37	30	77	58
Eastport (most eastern point of U. S.) Me.	44	54	66	56	Rochester, N. Y.	43	15	77	51
Exeter, N. H.	42	58	70	55	Sable (Cabe) S. cape of U S., Fa.	24	50	81	15
Frankfort, Ky.	38	14	84	40	Sacket's Harbor, N. Y.	43	55	75	57
Harrisburg, Pa.	40	16	76	50	Salem, Ms.	42	32	70	52
Hudson, N. Y.	42	14	73	46	Savannah, Ga.	32	2	81	3
Indianapolis, Ind.	39	55	86	5	Schenectady, N. Y.	42	48	73	55
Jackson. M'pi.	32	23	90	8	Springfield, Ms.	42	6	72	36
Jefferson, M'ri.	38	36	92	8	*Tallahassee*. Fa.	30	28	84	36
Kaskaskia, Il.	37	58	89	50	*Trenton*, N. J.	40	13	75	48
Lexington, Ky.	38	16	85	8	Troy, N. Y.	42	44	73	40
Louis, St. M'ri.	38	36	89	36	*Tuscaloosa*, Ala.	33	12	87	42
Middletown, Ct.	41	34	72	39	*Vandalia*, Il.	38	50	89	2
Milledgeville, Ga.	32	55	83	10	Washington City, D. C.	38	53	76	55
Mobile, Ala.	30	40	88	11	Worcester, Ms.	42	16	71	49
Montpelier, Vt.	44	17	72	36	Zanesville, Ohio.	39	59	82	10

Length of the longest and shortest days in some of the principal Cities of the United States.

	L. D. h.	L. D. m.	S. D. h.	S. D. m.		L. D. h.	L. D. m.	S. D. h.	S. D. m.
North part of U. S.	16	53.5	7	6.5	Washington,	14	43.8	9	16.2
Portland,	15	15.7	8	44.3	Richmond,	14	35.5	9	24.5
Portsmouth, N. H.	15	11.5	8	48.5	Raleigh,	14	18.6	9	41.4
Boston,	15	6.4	8	53.6	Charleston,	14	10.2	9	49.8
Providence,	15	3.0	8	57.0	Savannah,	14	5.8	9	54.2
New-York,	14	55.5	9	4.5	New-Orleans,	13	55.8	10	4.2
Philadelphia,	14	50.5	9	9.5	St. Augustine,	13	54.9	10	5.1
Baltimore,	14	46.8	9	13.2	Cape Sable, south point of U. S.	13	22.1	10	27.8
Cincinnati,	14	45.4	9	14.6					

TABLES OF THE CLIMATES.

1. *Climates between the Equator and the Polar Circles.*

Climates	Ends in Lat.	Where the longest Day is.	Breadths of the Climates	Climates	Ends in Lat.	Where the longest Day is.	Breadths of the Climates
	D. M.	H. M.	D. M.		D. M.	H. M.	D. M.
1	8 34	12 30	8 34	13	59 59	18 30	1 32
2	16 44	13 00	8 10	14	61 18	19 00	1 19
3	24 12	13 30	7 28	15	62 26	19 30	1 8
4	30 48	14 00	6 36	16	63 22	20 00	56
5	36 31	14 30	5 43	17	64 10	20 30	48
6	41 24	15 00	4 53	18	64 50	21 00	40
7	45 32	15 30	4 8	19	65 22	21 30	32
8	49 2	16 00	3 30	20	65 48	22 00	26
9	51 59	16 30	2 57	21	66 5	22 30	17
10	54 30	17 00	2 31	22	66 21	23 00	16
11	56 38	17 30	2 8	23	66 29	23 30	3
12	58 27	18 00	1 49	24	66 32	24 00	3

2. *Climates between the Polar Circle and the Poles.*

Climates	Ends in Lat.	Where the longest Day is	Breadths of the Climates	Climates	Ends in Lat.	Where the longest Day is.	Breadths of the Climates
	D. M.	D. M.	D. M.		D. M.	D. M.	D. M.
25	67 18	30 or 1.	46	28	77 40	120 or 4	4 35
26	69 30	60 2.	2 15	29	82 50	150 5	5 19
27	73 5	90 3.	3 32	30	90 00	180 6	7 1

A TABLE,

Showing how many miles make a degree of longitude, in every degree of latitude.

Deg. Lat.	Geo. Miles.	Eng. Miles.	Deg. Lat.	Geo. Miles.	Eng. Miles.	Deg. Lat.	Geo. Miles.	Eng. Miles.
1	59.99	69.06	31	51.43	59.13	61	29.09	33.45
2	59.96	69.03	32	50.88	58.51	62	28.17	32.40
3	59.92	68.97	33	50.32	57.87	63	27.24	31.33
4	59.85	68.90	34	49.74	57.20	64	26.30	30.24
5	59.77	68.81	35	49.15	56.51	65	25.36	29.15
6	59.67	68.62	36	48.54	55.81	66	24.40	28.06
7	59.55	68.48	37	47.92	55.10	67	23.45	26.96
8	59.42	68.31	38	47.28	54.37	68	22.48	25.85
9	59.26	68.15	39	46.63	53.62	69	21.50	24.73
10	59.09	67.95	40	45.96	52.85	70	20.52	23.60
11	58.89	67.73	41	45.28	52.07	71	19.53	22.47
12	58.69	67.48	42	44.59	51.27	72	18.54	21.32
13	58.46	67.21	43	43.88	50.46	73	17.54	20.17
14	58.22	66.95	44	43.16	49.63	74	16.54	19.02
15	57.95	66.65	45	42.43	48.78	75	15.53	17.86
16	57.67	66.31	46	41.68	47.93	76	14.52	16.70
17	57.38	65.98	47	40.92	47.06	77	13.50	15.52
18	57.06	65.62	48	40.15	46.16	78	12.48	14.35
19	56.73	65.24	49	39.36	45.26	79	11.45	13.17
20	56.38	64.84	50	38.57	44.35	80	10.42	11.98
21	56.01	64.42	51	37.76	43.42	81	9.38	10.79
22	55.63	63.97	52	36.94	42.48	82	8.35	9.59
23	55.23	63.51	53	36.11	41.53	83	7.31	8.41
24	54.81	63.03	54	35.27	40.56	84	6.27	7.21
25	54.38	62.53	55	34.41	39.58	85	5.22	6.00
26	53.93	62.02	56	33.53	38.58	86	4.18	4.81
27	53.46	61.48	57	32.68	37.58	87	3.14	3.61
28	52.97	60.93	58	31.79	36.57	88	2.09	2.41
29	52.48	60.35	59	30.90	35.54	89	1.05	1.21
30	51.96	59.75	60	30.00	34.50	90	0.00	0.00

REFLECTIONS

ON

ASTRONOMICAL TOPICS.

Believing it would best conduce to the utility of a work on Astronomy for schools, to have the scientific discussions uninterrupted, yet unwilling to dismiss these sublime themes without moral reflections, it has been concluded to subjoin a number at the end.

INTRODUCTION.

When the Psalmist says, "the works of the Lord are great, sought out of all them that have pleasure therein," we have the testimony of inspiration, that the TRULY PIOUS may have as high intellectual and social enjoyment from scientific researches and refinement of taste, as others, and in addition to these they may have *sublimer* and *holier* joys which result from discerning God every where. We may therefore rest assured, that the science of Astronomy can be profitably commenced in the early stages of common school education. And it can be made highly interesting and useful to all ages and classes in society. Legible and luminous inscriptions of WISDOM, POWER, and GOODNESS, infinitely great and glorious, tend to arouse all the intellectual and moral faculties of man, and turn them to the best account. And that religious feeling, which shrinks from mental expansion among the works of God, lest the fervor of piety should be chilled, can hardly be enlightened piety, or "zeal according to knowledge."

HISTORY.

Scepticism has attempted to invalidate the truth of Revelation, by pretending to find evidence of greater antiquity in the Chinese and Hindoo annals than is compatible with the Mosaic record. But the ablest philosophers have recently conceded, that no celestial phenomena, of which authentic records exist, can be traced farther back than some centuries subsequent to the inspired date of the deluge.

La Place has examined the Indian tables, in his *Systeme du Monde*, and left his testimony, to which none can object either his *incompetency* or his *superstition*.

"Every thing," says he, "leads us to conclude that they are *not* of high antiquity. They have two principal epochas, which go back, one to the year 3102, and the other to 1491 years before the Christian era. If we assume for our point of departure the epocha of 1491, and go back by means of the Indian tables, to the year 3102 before the Christian era, we obtain a general conjunction of the Sun, Moon, and planets, as these tables suppose; *but this conjunction differs too much from the result of our best tables, to have taken place, demonstrating that the epocha to which it refers is* NOT GROUNDED ON OBSERVATION."

"The whole system of the Indian tables," says Cuvier, "so elaborately conceived, *falls to pieces of itself*, now that it has been proved that this epocha was adopted *posthumously* from calculations *retrospectively* made, the result of which is *false*."

THE SUN.

If Herschel's theory of the Sun is correct, perhaps its luminous matter was called into existence in a more diffused state, at the moment when "God said let there be light;" and that it was concentrated about the body of the Sun, on the fourth day of creation.* However speculations of this kind

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* This hypothesis, exclusively the Author's, in the first edition, is found to be very similar to the following one from Professor URE's Geology, published in London, 1829.

"If created with the Earth on the first day, when the law of are viewed, who can fail to adore the inexhaustible energies of that Being, who kindled and has perpetuated the glories of that single material world.

Euler computed the light of the Sun, on each square foot of the Earth turned towards it, as equal to 6500 candles at one foot distance. Conceive then of the oceans of light, which are poured incessantly from the Sun on one hemisphere of this planet at 95 millions of miles from it. But 75 thousand such planets could succeed each other in the orbit of the Earth without contact; and there could be more than 3 thousand five hundred millions of such globes in the concave surface of a hollow sphere at the same distance from the Sun. But allowing space for the atmospheres, there could be more than 50 thousand planets in the *orbit* of the Earth, and more than 2 thousand five hundred millions in such hollow sphere, each one of which would receive an equal amount of light from that resplendent luminary, as the Earth now does. A similar computation would apply to the fertilizing influence of the Sun. How appropriately is this *creature* used in the Scriptures, as an emblem of its Creator! And yet all its effulgence is but *one ray* of created, material brightness, compared with the uncreated, essential and exhaustless effulgence of Jehovah's glory. What seraph's eye can bear to gaze on the unclouded splendor of glory, "dark with excessive brightness?"

When we have witnessed the brilliant colors of

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universal gravitation was ordained to govern heaven's isolated orbs; on the fourth day, the Sun was furnished with his phosphoric, or light exciting robe, a superficial luciferous film, which is probably the only peculiarity that distinguishes the structure of his body from that of his subject spheres."

the rainbow, and have considered the evidence, that a slight change in the configuration of the eye, could deck every landscape with countless millions of gems; we easily discern, that God can with infinite ease, place creatures in material worlds, with material organs of vision, in circumstances where equal effulgence should attend them every step, as those material images possessed, which are used in the Revelation to describe the glories of the New Jerusalem. Who shall say that immortal intelligences, formed to derive enjoyment from NOVELTY, BEAUTY, and GRANDEUR in the objects of contemplation, may not hereafter have pleasures, a thousand fold more intense, from the same sources, than they ever knew while here in the body. And yet the MORAL BEAUTIES in the Divine character and government, may then give joys immeasurably greater than all others.

MERCURY.

The human mind often derives its clearest conceptions, and strongest impressions, from comparisons rightly instituted. If we think of a ship sailing twelve miles the hour, the race horse moving twice as swift as the ship, or the bird flying with double the speed of the horse, we form some definite ideas of relative velocity. But how slow these motions compared with others. The tornado may have double the velocity of the bird's flight, and the ball propelled from the cannon's mouth eight times the velocity of the tornado, or moves eight hundred miles the hour. Still we have but begun to approximate to the velocity of Mercury's motion. It moves more than one hundred times as swiftly as the cannon ball.

Let us imagine ourselves on some commanding eminence, and waiting to witness worlds pass within one hundred miles of our position. The Moon is first seen advancing with the velocity with which it revolves around the earth. We gaze with wonder and admiration as it passes us at the rate of more than thirty miles the minute. Presently Mercury bursts on our astonished vision, and like lightning, rushes by us with the amazing velocity of thirty miles the SECOND. Who can restrain the exclamation? What power! the power of God!

But how small this manifestation of power, compared with all that is displayed, in the motions of material worlds, within the limited field of man's feeble vision.

Perhaps the more expanded mind of man in a future state of existence, with a medium of vision adapted to his enlarged capacities, may take in at one glance, the mighty movements of a whole solar system, with the same ease that he now contemplates the complicated movements of some well constructed orrery. Then a Newton will look back on his discoveries in time, as the intellectual dawnings of *mere* infancy.

Mercury basks in splendor seven fold brighter than Earth enjoys. Cherubim are surrounded with brighter intellectual splendors from the FOUNTAIN of all knowledge, than minds of mortals could here endure. But *that* splendor, and brighter than that, is reserved for all those who love to view the Sun of Righteousness.

VENUS.

The science of Astronomy, is adapted on the one hand to fill us with admiration, at the extent of man's intellectual powers, and the wonderful result of his investigations, and on the other hand, to abase human pride, that so little knowledge is possessed of a field of immeasurable extent, and indescribable beauty. By the light of this science, the philosopher confidently predicts the transits of Venus, which will occur in 1874, 1882, 2004, 2012, 2117, 2125, and calculates when they will commence, and when terminate, as seen from different parts of the Earth. This he does, notwithstanding he knows that other eyes, and not his own, will witness at those periods the appearance of Venus as a dark spot on the disc of the Sun. But why is a confidence felt, that these transits will take place? Because man has discovered, that God governs the material universe by fixed laws of admirable simplicity.

And has not Jehovah laws in his moral kingdom, as *wise* and as *immutable?* Cannot Infinite wisdom know with equal certainty every future event in his moral kingdom, as in the material universe? Can he not *even* qualify human beings to predict future events in his moral kingdom with unerring certainty? And when he has thus inspired them, as the result of their predictions prove, do not their messages deserve confidence? Have WE no means of determining what moral events will exist under the Divine government for centuries to come? Unquestionably we have. The predictions of REVELATION founded on the laws of Jehovah's moral government, in proportion as they are understood, afford ample assurance to faith, that they will be accomplished; whether they relate to the circumstances of Zion on Earth, or to the future destinies of moral character beyond the bounds of time. Blot out all confidence in the Oracle of God, mercifully given to ignorant, wandering and wretched man, and no bright harbinger of immortal day rises on his dreary night of adversity; no evening star of hope cheers the close of mortal existence. You leave his whole moral horizon SUNLESS and STARLESS. But let the Star of Bethlehem greet his renovated sight, it dispels the darkness of the grave, and gives promise of a heavenly day.

EARTH.

The wisdom, power and goodness of God are inscribed so frequently and legibly on man's habitation, that depravity alone can render its tenants unmindful of Him. It has been proved that the Earth is a vast globe; and geology teaches us, that even its immense mineral masses are formed with regularity and deposited with more than mechanical skill. Its surface is diversified with oceans and continents, lakes and islands, mountains and plains, hills and valleys. Did not wisdom plan its organized structure and its variegated surface? And when its landscapes were first clothed in all their beauty, and its forests first towered in all their pride, was not DIVINE GOODNESS painted on every flower and dropping from every bough and stalk where mature fruit fell to the fertile Earth? Contemplate the admirable simplicity with which its motion on its axis is turning its various parts, in quick succession, under the decorating and fertilizing influence of the Sun. View the angle its axis makes with its orbit, observe how it produces the regular return of summer and winter, seed-time and harvest, as well as day and night. Elaborate investigations have proved, that the Equatorial regions have less heat, and higher Latitudes more, as the Earth now revolves around the Sun, than if that luminary was always vertical at the Equator. Have atoms formed themselves, and originated such wonderful motions? Or did a Creator's power form and arrange them, and impart to them harmonious movements?

What must have been the emotions with which our first parents awaked in the maturity of their faculties, to behold this fair world fitted up as their residence? Would not they have beheld Divine perfections descending in Sun-beams, reflected from every object in the animal and vegetable kingdoms around them, and even inscribed on the very rocks? How gratefully would they have traced to God's hand their first repast. And ought not each one of their race, each day, to be as mindful of God, and as grateful for his favors, as man in innocence.

THE MOON.

The wonders of creation, which the microscope has disclosed to man, carry the mind into a boundless field of investigation, and constrain it to draw a thousand important inferences. Countless myriads of species having life are seen swarming in different elements. The single fig proves a populous world of conscious existence, when brought under high magnifying powers in a solar microscope. A single drop of water is often found to contain thousands of Animalcula. The individual daisy, and dandelion, each becomes a broad expanse, whose beautiful groves are perfuming their own atmosphere, and affording shelter for the winged tribes which nest and sing among their branches. Now suppose a tenant of such a grove should feel, that the Sun was made solely to adorn and fertilize his own *great world* the daisy. Perhaps no fellow tenant would presume to controvert his opinion. It is true their organs of vision might have discerned, at a vast distance from them, what seemed like another daisy, though less than the one they inhabited, but why conclude it filled with life? They could not discern its inhabitants.

Within the field of human vision there exists an object we call the Moon. Some of the tenants of Earth have learned to measure the distance between themselves and the Moon, and become acquainted with its real magnitude. They have invented telescopes, by which it *appears near them*, and is evidently diversified with hills and vallies, rocks and plains. If a large portion of its surface exhibits marks of volcanic action, and even its central parts are considered as yet a molten mass; some suppose the same is true respecting the Earth. And if, notwithstanding such an appalling hypothesis, our own world is full of beauty and being, cannot the Moon be likewise? Why may not lunarians be as really benefitted by larger measures of light from us, as we by a smaller amount from them? And why may not other planets and satellites in our system be filled with conscious existence or even intelligent beings? And the few daisies which surround our own, may be but a small part of the endless variety of flowers in the whole field of Creation.

When we think of the countless myriads of diminutive creatures with which this single planet is filled, and then recollect, that "the eyes of all these wait upon God, to receive their portion from his hand; that he opens it and fills them with good," we not only admire his condescension, but we are relieved from an apprehension that man will be overlooked in the dominions, and under the government of such a Being.

MARS.

It has been stated, that the redness of Mars is occasioned by the density of its atmosphere. Since the rays of the Sun have less effect upon the rare atmosphere on the tops of high mountains, than on the dense atmosphere at the surface of the Earth, is it not highly probable, that the surface of Mars may have as much warmth as this planet, though so distant from the Sun as to have but half as much light? We have no occasion, however, for believing that different planets have an equal amount of warmth in them, in order to their being filled with what is analogous to vegetable, animal, and intellectual existence on earth. The POWER and BENEVOLENCE, which gave life and enjoyment to inhabitants of the water where tenants of the land would instantly perish, may have adapted existence, and communicated happiness in millions of diversified circumstances in material worlds, of which we cannot now form any conceptions.

ASTEROIDS.

A conjecture was started that these small planets had formerly constituted but one. Should it be asked, if *physically practicable* for explosive force to rend a globe in fragments, the answer may be in the affirmative. It is believed that physical agents of sufficient energy to blow this earth in pieces exist in its materials. And if a moral cause be demanded for such an origin of the Asteroids, perhaps moral guilt was concerned, as in the desolation of the Earth by the Deluge.

JUPITER.

If organs of visions like ours exist in Jupiter and his satellites, the phenomena of their sky must be more interesting than our own. The rapid rotation of the primary on its axis, would occasion a perceptible motion of the Sun, the five hours it was above the horizon, and of the stars at night.

The Moons would be rising, setting, eclipsing the Sun, and being eclipsed; waxing to the full, and waning to the change in very quick succession. The nearest of the satellites would have Jupiter passing from one change to another in 42½ hours; and when at the full, appearing a luminary one thousand times as large as our Moon, and reflecting 40 times as much light.

One indication of benevolent design in the circumstances of the three nearest satellites, deserves particular notice. While they revolve in the plane of the primary's orbit about the Sun, they cannot fail to be eclipsed at every time of their full, yet their orbits are so adjusted, that these three cannot all be eclipsed at the same time in many thousands of years.

If this can be attributed to chance, what can be traced to design?

SATURN.

This planet, it will be recollected, revolves on its own axis, and around the Sun, in periods to render a day at the Equator little more than five hours, while at the poles it is almost fifteen years. Though its light by day is but one ninetieth part of what we enjoy, a wonderful provision has been made for supplying it with reflected light.

Let us conceive ourselves transported to this most splendid object of telescopic vision. We will choose to alight in the northern hemisphere when the Sun is at the winter solstice. The lamp of day has illumined the horizon perhaps less than two hours. When that sinks from view, arches of light begin to be visible in the east, and presently stretch themselves across the heavens, becoming more and more luminous, till bands of burnished silver would have less brilliancy, and ten full Moons impart less light. This scene of splendid effulgence, would pour its ceaseless tide of beauty on the north pole, for almost fifteen years, while deprived of the light of the Sun. Besides these rings of glory, our eyes might behold Moons rising and setting, horned, in quadrature, gibbous, full, passing into an eclipse, or emerging from one, while a starry firmament of equal extent and sublimity as at the Earth, would lend its twinklings to complete the scene. How short such a night would seem could we but enjoy its beauties! And are we to believe that all is sterility and silence there? Shall we not rather presume, that intelligences are there adoring the wisdom and goodness which has so adorned their habitation? But it may well abate our own self-importance to be informed, that organs of vision like ours on Saturn, would not, without a telescope, even know of the existence of Earth, important as an inch of its soil appears to *men*.

COMETS.

Man is under no inconsiderable obligations to Astronomy for its influence in allaying a thousand fears which ignorance of celestial phenomena raised. Until the 16th century, no comet could shed a transient ray on Earth without filling a guilty race with consternation. The gravest historians inserted on the same page with every comet's appearance, some direful calamity as its certain attendant. But while it is now known, that comets are obeying kindred laws with the planets, much ignorance exists respecting their minute circumstances. They cannot be exceedingly dense bodies, as Newton supposed them, as their attraction is extremely small. If they are very rare bodies, which it is now generally conceded they are, the Newtonian theory of caloric must be abandoned, as the intense rays of the Sun in their perihelion would inevitably dissipate them. And the conjecture of Whiston, that they may be prisons of Omnipotent justice where agonizing alternations of heat and cold are endured, is as visionary in philosophy as in religion.

It has been hinted as *possible*, that a comet might come in contact with a planet. Suppose that of the hundred comets, the elements of which have been computed, the chance is not one to one hundred thousand, that either of them can impinge against the Earth; who shall assure us that of the four hundred other comets which are supposed to exist in this system, some one, the elements of which have not yet been computed, may not presently appear in the heavens, and within a month have its possible contact, an awful reality in which death and desolation should be instantly rolled over man's habitation? Does a chill of apprehension involuntarily seize us at the bare supposition, at what would we value relief from such dread?

We have in our hands a volume which professes to have come from Him who revolves both planets and comets in their orbits. There it is predicted, that certain moral purposes are to be accomplished on the Earth before it shall be destroyed. In proportion to our faith in that volume, our fears may subside, and we may clasp it to our hearts with warmer emotions of gratitude.

THE FIXED STARS.

In this article, it will be considered as having been already proved, that the nearest fixed stars are so distant that they must be suns; and that the unassisted eye might behold from the surface of this planet, more than two thousand. It will be assumed, as not improbable, that kindred planets in our system are full of conscious existence, and perhaps intelligent moral agency; and that kindred suns may be attended with retinues of worlds, wonderfully exhibiting to creatures in them, the exuberant goodness of their Creator.

But the mind of man labors exceedingly when attempting to grasp some clear conceptions of that space which one solar system occupies. The nearest fixed star is known to be more than two hundred thousand times as distant as the Sun. Consequently, the Sun is exerting a controlling influence in every part of a hollow sphere around it, at least half that distance. But a cannon ball moving with the velocity of eight hundred miles the hour, would be more than thirteen years passing over the one hundred thousandth part of such a distance; of course more than a million of years passing over the whole space.

Limited as the faculties of man appear, when attempting to explore such portions of space as come before him in surveying the fixed stars, where shall we set limits to their expansion? I stand on a plain, and my eye takes in but a small field of vision at once. I ascend a hill and a much larger field is transferred through the eye to the mind's survey. I climb a mountain, and from its lofty summit, a sublimer expansion is spread on the retina of the eye. Bring to the aid of my feeble organs of vision a telescope. In one direction, or one point of the field before me, I have a still more enlarged view. Now if my eyes were constructed to magnify objects as much as the lenses of that telescope, why might not my mind grasp a much wider range of objects at once, than it can now do through the contracted powers of my organs of vision? And may not this mind be so expanded when acting through a more favorable medium, that it can view the complicated circumstances of a whole solar system, with the same ease with which it now surveys the objects of a single landscape?

Suppose such intellectual powers actually possessed by one of our race, when this mortal shall have put on immortality. Suppose that in the exercise of these faculties, he contemplates WISDOM and GOODNESS, as displayed in the properties of the elements which constitute and surround the Earth. He sees attraction and repulsion, in the chemical properties and movements of what man calls inanimate matter; assorting and classifying its minute particles, moulding them into forms of perfect regularity, and combining them in ways to reflect an endless variety of exquisite brilliancy and beauty. He sees *matter* in its larger masses located, arranged, and proportioned in an admirable manner, to subserve purposes of vegetable and animal existence, and afford conveniences and treasures for man's use. He surveys that sublime expansion of fluid matter, which is both the fountain and reservoir of all the waters which refresh the land. "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come thither they return again." To prevent its putridity ana its diffusion of pestilence, it is impregnated with salt and agitated with tides and winds. It facilitates the intercourse between distant parts of the world for commercial and religious purposes. Evaporations from its surface supply needful humidity to the atmosphere. He sees the surface of islands and continents, into which the dry land is divided, beautifully diversified with hills and vallies, where pure springs rise and fertilizing rivers flow. An elastic fluid mass encompasses both land and water. The transparency and rarity of this, admit all the benefits and beauty of light, bending the rays of the Sun to give us an earlier day, a later evening, and a brighter sky; while it is sufficiently dense to support clouds and subserve the purposes of respiration. An electric fluid and continual circulation, make it pure and salubrious. In the spring and summer, exhalations from the vegetable kingdom, render it peculiarly exhilarating and aromatic.

To a mind capable of grasping the whole range of botanical science, vegetation would be seen perfectly adapted to the various climes and seasons and wants of a world. "From the cedar of Lebanon to the hyssop under the wall;" from the royal oak to the humblest lichen of the rock; whose seed is in itself, each after its kind, inscriptions of wisdom and goodness would every where meet him in the verdant green of the wide spread landscape, the variegated hues and fragrance of its blossoms and flowers, and in its "swelling, coloring, ripening fruit." But the minuter indications of benevolent design which pervade every part of the vegetable world, I have neither time nor ability to disclose.

Suppose this being of enlarged intellectual powers surveying the animal kingdom. There the structure of each body, with its diversified members, would all be found admirably adapted to the elements, the circumstances, the habits of life, for which each animal was designed. The myriads of creatures swarming in the different elements, would be usually seen in a state of actual enjoyment, and often in abundant measures.

Perhaps, that mind would discern that ALL the sufferings endured by animals are in consequence of sin's having entered the world. Who will venture to affirm, that God could not with equal ease have caused all animals to be as perfectly free from suffering every moment of their existence as one moment? Could he not even have caused their dissolution to be as free from suffering as their falling asleep? And may we not add, that perhaps the animals of millions of material worlds commence, continue, and close their existence, without the least degree of suffering. If animals do exist where sin is unknown, may they not be supported by a similar provision to that which JEHOVAH SEEMS to have made for animals on Earth, before the fall? "To every beast of the Earth, and to every fowl of the air, and to every thing that creepeth upon the Earth wherein there is life, I have given every green herb for meat, and it was so." Here was no commission given, *perhaps*, no inclination existed, to take the life of each other.

Let us suppose, that displays of wisdom and benevolence are next surveyed in the intellectual world. Behold a capacious and immortal mind, on Earth inhabiting a clay tenement, "fearfully and wonderfully made," constituted and adapted to be the medium through which the soul acts, and is acted upon. Compute man's enjoyment arising from sensible objects, from the social affections, and from the cultivation and refinement of his intellectual powers. Aside from the effects which sin has produced in man, and in the world, each energy of the human mind, and each sensitive power of the body, is so adapted to the objects with which it is conversant, that it would be soothed, refreshed, and delighted continually. Unquestionably, a devout mind qualified to discern at once all the indications of benevolent design which attend inanimate matter, vegetable and animal existence, together with the physical, mental, and moral circumstances of man, would exclaim, "O Lord, how manifold are thy works, in wisdom hast thou made them all; the Earth is full of thy riches."

But the intellectual powers of a creature, have been supposed adequate to a simultaneous and minute survey of all the circumstances of every other world, belonging to our solar system. Suppose each planet, though peculiar in all its circumstances, exhibiting as legible inscriptions of wisdom and benevolence as the Earth. Let the Sun be seen in larger measure and brighter beams, reflecting these attributes of the Creator. And let all the diversified minute circumstances, and the sublime harmonious movement of the whole system, converge their rays to one point; what effulgence of wisdom and goodness would blaze intensely there. And what adequate estimate can be made of the power which created, sustains, and governs this single system of worlds. But two thousand suns can be seen without a telescope. Suppose each the centre of a system peculiar in some of its circumstances; and each planet in each system diverse from every other planet, and solids, and fluids, and what is analogous to vegetable and animal existence on Earth, with endless diversity proclaiming what is every where seen in our own system.

Some of these systems have two, some three some four, and others more than four Suns. The mind that knew the minute circumstances of one system, might not be able to imagine the material glories of some of the others.

What glories of wisdom, and power, and goodness rush on the conceptions of even mortals on Earth, when glancing at the circumstances of thousands of Suns. But the telescope discloses evidence of the existence of many millions. And these millions may be but a small item among the countless millions which exist immeasurably beyond the reach of man's power to explore. Now the wisdom and power requisite to plan and create, and the goodness exhibited in sustaining and supplying Suns, and worlds, and creatures, so inconceivably numerous, immeasurably exceeds all our conceptions. And the interrogation of the Divine Oracle has an emphasis never before discovered. "Who by searching can find out God? Who can find out the Almighty to perfection?" What limits shall ignorant, impotent mortals set to the exercise of God's power? Because on Mars' hill and elsewhere, some self-styled philosophers have mocked, when the resurrection of the dead was named; is there any foundation for the opinion, that He who spread out these heavens as a curtain, cannot wake our race from the slumbers of the grave? CREATION should teach man this lesson of humility, that "God can do all his pleasure." We have only to inquire what he has revealed as his purpose to accomplish, and rest assured that it can, and will be performed.

Does scepticism insinuate, that since the dominions of the Creator are so extended, he must overlook the dark atom which we inhabit, and the diminutive race to which we belong? This cavil directed against revelation, rests solely on a false estimate of the Divine attributes. None but an atheist denies that God is omnipresent and omniscient, and when the Deity is clothed with these attributes, it follows unavoidably, that he can be as minutely present with each world, and each creature, and each thought in his dominions, as though that world, or that creature, or that thought, ALONE existed.

In the light of countless millions of Suns, let us attempt to form some conception of Omniscience. That Being who is perfectly acquainted with the mightiest movements and the minutest circumstances of every system, every world, and every creature, in the immeasurably extended universe, we call *omniscient;* but is all this knowledge omniscience? It is merely one ray compared with the Sun. Though the immortality which is before man, is sufficiently long for him minutely to survey all the circumstances in each system we have supposed to exist, if such were the Creator's pleasure; yet the resources of Jehovah for the continual enlargement and employment of finite intelligences would forever remain exhaustless. Truly "his understanding is infinite."

Converge the rays of countless millions of Suns on the evil of sin, and who shall estimate its demerit. It overlooks the wisdom, contemns the power, and abuses the goodness which pervades the whole universe. It tends to roll a wave of moral desolation over the whole empire of the Eternal, blotting out every thing which is bright and annihilating every thing which is good. How much less than an infinite evil is sin? Who shall say, that ETERNAL LOVE has not erected in his dominions an adamantine prison, where *everlasting chains* are reserved for unreclaimed sinners? Does the thought arise, since millions of material worlds exist, supposed to be the centres around which multiplied millions of other worlds revolve, each supposed to contain hundreds of millions of moral agents, may not sin and suffering have entered them? It may be replied, that perhaps all of them are as the earth would have been, had sin never entered it. Or if sin has introduced moral desolation into other material worlds, the provisions for its pardon made here may have efficacy even there. But scepticism sneeringly asks, "is it likely Eternal Majesty would stoop, as the Scriptures teach us he has done, to regard the circumstances of an insect race on a mere atom in his dominions?" Scoffing mortal, take your microscope and survey a universe of diminutive tribes to which infinite condescension is extended. Lift your eyes to the heavens. Are not *infinite* wisdom and *infinite* power inscribed there? And will you reject the testimony of revelation, that God's condescension and mercy towards guilty man, are like his other attributes, *infinite?*

A survey of the extent of the material universe, may be instrumental of eliciting and inflaming a better train of feelings. The heart may breathe out aspirations to God. "When I consider thy heavens, the work of thy fingers, the Moon and the stars which thou hast ordained; what is man, that thou art mindful of him, and the son of man, that thou visitest him. Whole nations are indeed in thy sight as a drop of the bucket, or a small dust of the balance, yea all nations are counted to Thee as nothing, and LESS THAN NOTHING and vanity. Though the high and lofty One inhabiting eternity, wilt thou extend thy kind regards to him, who is of an humble and contrite spirit? Wilt thou even regard the prayer of the destitute?"

And has the dust of this planet been moistened with the tears, and crimsoned with the blood of the Lamb? And shall such an infinite sacrifice for man be disregarded by any to whom the news of unparalleled condescension and infinite mercy are proclaimed? And can such guilt unpardoned, fail of aggravated condemnation? And shall any doubt be cherished by those who have embraced the hope of the gospel, that minor blessings which they may need shall be withheld from them by Him who has the resources of the universe at His disposal? Can He want for means to execute His most tremendous threatenings or fulfil His most glorious promises? Suppose He has promised each subject of His grace a mansion too bright for the Sun to be a lamp in it, can HE not fulfil such promise? Can He not give immortal glory to His friends, a glory which shall become more and more refulgent, when all this drapery of material glories shall be folded up and laid aside as a worn out threadbare garment?

When contrasting the attributes of the Creator with the circumstances of his creatures, what cause for humility? Is it not *folly* to arraign such wisdom? Is it not the blackest ingratitude to abuse such goodness? Is it not madness to contemn such power?